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Uniform Engine Testing Program Phase VII: NASA Lewis Research Center Second Entry

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PREFACE

This report presents a summary of the results of tests conducted at the NASA Lewis Research Center, Cleveland, Ohio, U.S.A., as part of the AGARD Uniform Engine Testing Program. The format used for the report is that specified in the Uniform Engine Testing Program General Test Plan, dated June 1983.

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UNIFORM ENGINE TESTING PROGRAM

PHASE VII: NASA LEWIS RESEARCH CENTER

SECOND ENTRY

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1.0 INTRODUCTION

The Propulsion and Energetics Panel, Working Group 15, of the Advisory Group for Aerospace Research and Development (AGARD) is sponsoring a program it has named the Uniform Engine Testing Program (UETP). In the UETP, two jet engines, one primarily an altitude engine and the other a sea-level engine, are being tested under similar conditions in a variety of altitude and ground-level facilities as a means of correlating performance data from these facilities. Table I contains a list of the facilities participating in the UETP in order of participation. The general test objectives of the UETP, as stated in reference 1, are to upgrade the standards of turbine engine testing within AGARD countries and to establish the reasons for observed differences between engine performance as measured in ground-level and altitude facilities.

Interest in the UETP was generated in part by a program in which the same model of a C-5A aircraft was tested in a number of wind tunnels. A direct result of this program was an improvement in the quality and overall compatibility of such data. Until the same model was run at comparable conditions, differences in results among facilities could be explained away, but not necessarily for the right reasons. After the same model and balance were tested in different wind tunnels, strengths and weaknesses in procedures could be assessed. Differences that existed were resolved, and the best procedures of each facility were adopted for local usage.

NASA conducted the first tests in the UETP. It was responsible not only for its own hardware, instrumentation, and operational costs, but also for initial program management and procurement of some hardware and instrumentation for use in the remaining phases of the UETP. A report on the results of the initial testing of two J57-19W turbojet engines in a NASA altitude test facility in support of the efforts of the AGARD panel can be found in reference 2.

The purpose of the second NASA entry, the subject of this report, was to document any engine deterioration that may have occurred since the first NASA entry by repeating selected test conditions run during the first entry. This would allow adjustments to be made to the UETP data to eliminate differences that might have occurred because of engine performance changes between the two NASA entries. During the time between the two NASA entries the engines were tested at the facilities as shown in table I.

Also, NASA investigated several anomalies discovered during review of data from the facilities which had participated in the program between the two

entries. Generally, these anomalies can be categorized as difficulties in measuring the exhaust nozzle inlet total pressure, a suspected change in nozzle exit area, and an engine inlet total-pressure variation (i.e., inlet radial distortion) due to different geometry inlet ducts at the participating facilities.

This report presents the results from the second NASA UETP entry. These results are intended to assist Working Group 15 in analyzing the UETP data and resolving differences between facilities through the following:

(1) Documentation of engine performance differences

(2) Improved definition of the exhaust nozzle inlet condition and the nozzle coefficients

(3) Quantification of the effects of different inlet duct geometries

(4) Documentation of engine performance changes due to nozzle area change.

2.0 APPARATUS

This section briefly describes the major items of the test installation at NASA. The two engines, compressor bleed, oil cooler, bullet nose, fuel type, and instrumentation were the same as those described for the initial tests (ref. 2). One slight change in emphasis during the time between the first and second entries was the Working Group's decision that engine S/N P-607594 would be designated the altitude engine and engine S/N F-615037 would be designated the sea-level engine. Figures 1 and 2, from reference 2, show a schematic layout of an engine and the instrumentation locations, respectively. In addition a list of symbols can be found in appendix A. The differences that occurred in the facility, bellmouth-inlet ducting, and tailpipe are described next.

2.1 Facility

The facility was the same as that described in reference 2 except that the engine tests were performed in test cell 4 of the Propulsion Systems Laboratory (PSL), which is identical to test cell 3, where the first UETP tests were performed. The change was necessary in order to minimize a problem with hot gas recirculation through a bypass line which was encountered in test cell 3. (See ref. 2, section 4.2.1.1 for a description of the problem.)

2.2 Bellmouth and Inlet Ducting

The bellmouth and inlet ducting, which were sized for a design Mach number of 0.6 at station 1.0, were the same as those used in the first entry (ref. 2). A second bellmouth and inlet duct, of larger diameter (fig. 3) and sized for a design Mach number of 0.36, were added to the program to investigate the effect of engine inlet total-pressure profile on engine performance, particularly inlet airflow rate.

2.3 Modified Tailpipe and Reference Nozzle

Since the tailpipe and nozzle were the same as those used in the first entry (ref. 2), a second nozzle calibration was not necessary. Particular attention was paid to the nozzle exit diameter measurements and nozzle entry total-pressure profiles because of differences related to P7 among the various facilities. In addition two exhaust nozzle exit area A8, restrictor blocks (fig. 4), positioned 180° apart, were added for one test sequence to document the effects on engine performance of a nozzle exit area change.

3.0 TEST DESCRIPTION

3.1 Test Conditions and Procedures

This description of test conditions is divided into two parts: (1) test points to document engine deterioration since the initial testing at NASA (table II) and (2) test points to investigate anomalies discovered during the review of data from other facilities that participated in the UETP.

3.1.1 <u>Deterioration documentation</u>. - Test conditions were selected from those shown in table II to document engine deterioration. Prior to the second NASA entry it was proposed to and accepted by Working Group 15 that a shortened test matrix consisting of test conditions 1, 3, 6, 9, and 10 be employed. Both engines were tested at these conditions. The test procedure remained unchanged (i.e., UETP General Test Plan Procedure (ref. 1)). The determination of thrust calibration terms was also the same as described in reference 2, but an airflow measurement station traverse was not performed.

3.1.2 <u>Engine inlet total-pressure profile investigation</u>. - Analysis of data from the UETP participating facilities uncovered variations in engine inlet total-pressure profile from facility to facility. The effect of this total-pressure variation (i.e., a tip radial distortion) on engine performance was investigated at NASA through the use of a larger diameter inlet duct than that used for the UETP test conditions. Test conditions 6 and 9 were selected for this investigation.

3.1.3 <u>Tailpipe rotation</u>. - During the first NASA entry it became apparent that the station 7 total-pressure rakes chosen for the UETP did not adequately measure this pressure (ref. 1, section 3.2.1). The pressure profile at station 7, the nozzle entry, appeared to be strongly influenced by the large turbine exit struts and the turbine exit swirl. In an effort to better understand the nozzle entry total-pressure profile and to investigate the variations in nozzle entry static pressure, the tailpipe was rotated about the engine horizontal axis in 10° increments from 20° counterclockwise to 20° clockwise from the base position specified for all UETP participants. The tailpipe rotation resulted in the station 7 instrumentation also being rotated by these increments. Thus, a more complete survey of the total-pressure profile could be made. Test conditions 6 and 9 were used for this investigation.

3.1.4 <u>Nozzle exit area change</u>. - There was some concern that an exhaust nozzle area A8 change had occurred during the course of the UETP. This was not confirmed by exit area measurements. Nevertheless, a test was performed with two nozzle area restrictors (fig. 4) positioned 180° apart installed at station 8. The restrictors reduced the exit area by approximately 2 percent.

Test condition 6 was rerun with the nozzle in this configuration, and the data were compared to those taken without the restrictors to document the effects on engine performance of a change in exhaust nozzle area.

3.2 Corrections

Fuel flow oscillations induced by an erratic facility fuel pressure regulator were large enough that the precision or random error for fuel flow rate for engine S/N P-607594 was greater than that estimated for the measurement uncertainty analysis. The engine fuel pump apparently attenuated the oscillations with the result that the engine fuel flow rate signal had less of a precision error. For most of the tests a substitution of engine meter data for facility meter data was not made because of the desire to compare data from the first and second entries. The one exception was the substitution of engine fuel flow meter data for the facility fuel meter data for test condition 3, engine S/N F-615037, due to excessive electrical noise on the facility meter data channels.

The temperature distortion problem in test cell 3 noted in section 2.1 was minimized in test cell 4 as shown in figure 5, a comparison of a weighted T2 and the average T2 for two low ram ratio cases, test conditions 1 and 3. A dramatic improvement is shown for test condition 1, the lowest engine inlet temperature, where there was almost a 1 percent better (i.e., more uniform) temperature distribution. This was one of the considerations in switching the UETP entry from one test cell to the other.

It was necessary to limit the inlet total pressure for test condition 1 to something less than the desired 82.7 kPa and outside the required setting tolerance specified in the UETP General Test Plan (ref. 1). This low ram pressure ratio condition required a larger amount of test cell cooling air which resulted in facility restrictions on the exhaust collector pressure. At this lower pressure, approximately 81 kPa, the data do not seem to be adversely affected. In addition the station 1 total-pressure probes at 80° and 350° were removed from the average total pressure because of suspected icing.

3.3 Data Reduction

The data reduction package is the same as that described in reference 2 with a few exceptions. The digital data acquisition and processing system for this second UETP entry at NASA is shown in block diagram form in figure 6. The on-line, or real-time, monitoring of the engine tests was accomplished by using an ESCORT III system (ref. 3) consisting of a PDP 11/34A computer located at the test facility, which was linked to a VAX 11/780 supervisory computer of the central computing system. The update rate using this system, and thus the frequency with which data could be recorded, was set at 1.5 sec as opposed to the 1.0 sec for the first entry (ref. 2). In addition the multiple pressure scanning system used in the first entry was replaced with a transducer per channel system for the second entry (ref. 3).

When the engines and hardware were shipped from NASA after the second entry, the instrumentation (fig. 2) identified as unserviceable, or at least suspect, was WFE1 for engine S/N P-607594 and PS2B28, P7D10, P7J10, TM7A29, T7B01, T7H01, and T7P19.

3.4 Uncertainty/Precision of Measurement

A complete error audit, including an identification of the elemental error sources, their types (i.e., bias (fixed) or precision (random)), and their magnitudes, and the estimation of performance parameter uncertainties, was done by M. Abdelwahab and D. Silver at the request of Working Group 15. Preliminary results of this error audit are summarized in table III.

4.0 TESTING RESULTS

4.1 Techniques Used for Data Analysis

The techniques used for data analysis were the same as those used for the first entry and are described in reference 2, section 4.1.

4.2 Results

The results are categorized under deterioration and the effects of inlet geometry change, tailpipe rotation, and exhaust nozzle exit area change.

4.2.1 Engine deterioration. - The bar charts in figure 7 show the differences in engine performance for the two entries in terms of speed ratio, referred airflow rate, fuel flow rate, net thrust, and engine temperature ratio as a function of engine pressure ratio PS7Q2. Except for anomalies in WFR and FNR for S/N P-607594, which are addressed, there does not appear to be a strong case for engine deterioration.

The changes between entries 1 and 2 for engine S/N P-607594 in terms of speed ratio and referred airflow rate, fuel flow rate, engine temperature ratio, and net thrust are shown in figure 7(a). As with the other engine in the program, speed ratio decreased for all conditions tested (test condition 3 was not run for the first entry) ranging from 0.15 percent to slightly more than 0.3 percent. Airflow rate changes were from slightly less than 0.5 to 1.5 percent for test conditions 6, 9, and 10 (ram ratios greater than 1.0) and within the measurement uncertainty for airflow rate as presented in table III. The decrease in airflow rate for test condition 1 of almost 1.5 percent is most likely attributable to the temperature distortion encountered during the first entry. The fuel flow rate differences have a much greater variation than any of the other parameters, -0.35 to almost +3 percent. Even the repeatability is greater than 1.5 percent. (Repeatability is defined in sec. 4.2.2.) If the engine temperature ratio T5Q2 is used as an indicator of energy input in place of WFR, the differences between the two entries are more consistent. The engine temperature ratio increased for all test conditions from approximately 0.05 to 0.4 percent for conditions 6, 9, and 10. For test condition 1 the difference was approximately 1 percent, which is slightly greater than the uncertainty for engine temperature ratio as represented by T7Q2 (table III), a similar measurement. Again this may be attributed to the temperature distortion encountered for conditions at a ram ratio of 1.0 for the first entry, which would have affected the engine inlet temperature T2AV. An oscillation in the facility fuel supply pressure which was evident in the facility fuel flow meters for the second entry (sec. 3.2) may be the cause of the discrepancies between the results using WFR and T5Q2. The net thrust

differences of 0.5 to 0.75 percent for conditions 1, 6, and 10 are consistent with those for the other engine. The difference for test condition 9 of almost 3 percent is the greatest net thrust difference for either engine. This could be associated with the difficulty in measuring low thrust levels associated with condition 9, a high-altitude case. Except for the anomalies noted for WFR and FNR, it would appear that if deterioration did occur, it was slight.

For engine S/N F-615037 (fig. 7(b)), the speed ratio differences between the two entries decreased for the five test conditions from 0.25 to 0.5 percent and the fuel flow rate differences increased from near 0.5 percent to slightly more than 1.0 percent. This is consistent with engine deterioration if it occurred. However, at the same time airflow rate differences change less than 0.35 percent, and net thrust differences increase from less than 0.2 percent to about 0.5 percent. Both the airflow rate and net thrust increases are within, or at least close to, the repeatability differences between the first and last test conditions run for the second entry. Also, they are within the uncertainty bands for these parameters as shown in table III. The fuel flow rate is also within the uncertainty bands.

4.2.2 Repeatability. - For the purposes of this report, repeatability is defined as the difference in selected parameters between the first and last test conditions run for each engine. In general, repeatability as shown in figure 7 was good, less than 0.25 percent with one exception.

Repeatability of engine S/N P-607594 data (fig. 7(a)) was within 0.1 percent for the speed ratio and within 0.25 percent for referred airflow rate, net thrust, and engine temperature ratio, but greater than 1.5 percent for referred fuel flow rate. This fuel flow rate anomaly is explained in section 3.2.

It was decided to use a test condition 6 that was not in the last series of runs before engine S/N P-607594 removal because an inlet duct change had occurred. Additionally, atmospheric air rather than the normal conditioned inlet air was available and used.

Repeatability of engine S/N F-615037 data (fig. 7(b)) was within approximately 0.2 percent for the speed ratio, referred airflow rate, fuel flow rate, and net thrust.

4.2.3 Effects of tailpipe rotation. - Figures 8 to 13 show the changes in exhaust nozzle inlet total and static pressures, selected engine performance parameters, and nozzle coefficients with tailpipe rotation. The purpose of this investigation is explained in section 3.1.3. In particular, figure 8 shows the changes in total-pressure profiles for each of the nozzle inlet instrumentation rakes with tailpipe rotation. Section 3.1.3 contains an explanation of how the tailpipe rotation and the nozzle inlet survey are related. The largest effect is evident at the outer diameter with lesser effect closer to the tailpipe centerline. The total-pressure variation is summarized in figure 9, which shows the variation at positions approximately equal to 50 and 100 percent of the exhaust nozzle inlet area A7. The data points represent the average total pressure for each station 7 instrumentation rake normalized to the average static pressure for each of the tailpipe positions. The dashed lines represent the assumed total-pressure profiles based on the measurements from the closest instrumentation rake in the clockwise direction. Also shown are the positions of the turbine exit struts as

represented by the centerline of each strut. If the flow from the turbine has no swirl angle, its minimum pressures should be in line with the struts. However, the data shown in figure 9(b) are offset at least 20° to 25° in the counterclockwise direction between the strut centerlines and the minimum total pressures. The assumption, then, is that the flow exiting the turbine has a 20° to 25° counterclockwise flow angle from the engine centerline when it reaches the nozzle inlet instrumentation. In figure 9(a) the total-pressure variations are not as pronounced as those shown in figure 9(b), but the minimum pressures appear to be about 15° offset in the counterclockwise direction from the centerlines of the turbine exit struts. With the assumption that more swirl occurs at the turbine tip than at hub or midspan, an argument can be made for the flow angle at the outer diameter being 20° to 25° if the angle is about 15° at midspan. The obvious conclusion from these two figures is that circumferential position has relatively little influence on the total-pressure measurement near the 50-percent-span position but a large effect on the total pressure at the outer diameter.

Also, an investigation was conducted to find a pressure in or near the tailpipe that was relatively insensitive to flow variations caused by the turbine that could be used to calculate a representative engine pressure ratio. The results of this investigation are shown in figure 10, where the variations of P7, P5, PS7, and tailpipe pressure loss are plotted. In figure 10(a), engine pressure ratio as represented by PS7Q2 and P5Q2 is relatively insensitive to tailpipe rotation. Therefore, it can be assumed that PS7 and P5 are more truly representative of actual conditions when the tailpipe is in the base position than P7.

Figure 10(b) shows the tailpipe pressure loss calculated by using the measured P7 and a derived P7 based on the measured PS7 and the nozzle entry to exit area ratio for the fixed-area conical nozzle. As would be expected from the previous discussion of P7 and PS7 variations with tailpipe rotation, the tailpipe pressure loss based on the measured PS7 produced much less scatter than that based on the measured P7, which is influenced by the presence of the turbine exit struts.

To confirm that engine performance had not changed to any significant extent during tailpipe rotation, engine pressure ratio, as represented by PS7Q2, was plotted against referred high rotor speed (fig. 11). No significant variation was seen.

In contrast, large variations were observed in the nozzle coefficients CG8 and CD8 during tailpipe rotation for test conditions 6 and 9, as can be seen in figures 12 and 13. These figures indicate the importance of obtaining a good description of the station 7 total-pressure profile if the calculated nozzle coefficients are to be of similar magnitude to the theoretical data for the 15° convergent nozzle used in the UETP. The positions clockwise from the base position resulted in the highest nozzle coefficients with the exception of CD8 for test condition 9 (fig. 13(b)).

Because the changes in the coefficients CD8 and CG8 (fig. 12) appeared to be large given the changes in P7Q2 (fig. 10(a)), an investigation was conducted into the sensitivity of these coefficients for the given P7 changes. The results at the target high rotor speed of 8900 rpm for the 10° clockwise and 10° counterclockwise tailpipe rotations were used because these data

represented the widest variation in CG8 and CD8 (fig. 12). It was determined from these data that the results were consistent as follows.

The change in P7 between the two tailpipe positions was approximately -3.5 percent, while the change in CG8 (fig. 12(a)) was approximately +3.8 percent. Using a sensitivity factor, determined by taking the partial derivative of CG8 with respect to P7, produced a theoretical change of +5.1 percent in CG8. The difference between the actual and theoretical changes can be attributed to changes in other parameters, brought about by setting condition differences, which influence CG8 such as gross thrust FG and test cell ambient pressure PAMB. These changes precluded CG8 from changing the amount predicted for an ideal situation where only P7 changes. With the changes in FG and PAMB included, the theoretical change was approximately +4.3 percent. The changes in TM7 and A8 which can also influence CG8 were considered insignificant.

The change in P7 of -3.5 percent between the two tailpipe positions produced a theoretical change in CD8 of +3.6 percent based on a sensitivity analysis using the partial derivative of CD8 with respect to P7. However, the actual change in CD8 was only +1.9 percent for the two positions (fig. 12(b)). If the total differential of CD8 is used in place of the partial derivative with respect to P7, the influence of other parameters such as WA1, T7, and WF, which have a bearing on CD8, can be considered. In fact these parameters must be considered because they did vary, though slightly, for the two test positions. If the influence of these parameters is included, the theoretical change in CD8 is +1.9 percent, the same as the actual change. Any changes in engine exhaust nozzle metal temperature TM7 and area A8 can also influence CD8, but they were not included because they were considered insignificant.

4.2.4 Effects of inlet duct change. - It is obvious from figure 14, a plot of engine inlet total pressure P2 against flow area, that the NASA total-pressure profile with its normal UETP inlet duct (see sec. 2.2) shows a large variation from an ideal or flat total-pressure profile as represented by the NRC-Canada inlet profile measured on their ground-level test bed (ref. 4). In the same figure, the larger NASA inlet duct shows a dramatic improvement in the profile. To explore the effects of inlet pressure profile, data were obtained with the larger inlet duct as explained in section 3.1.2.

Examination of the effects on engine performance of these two inlets (figs. 15 to 18 and table IV) showed that for test condition 6 the relation between the engine low- and high-pressure compressors (represented by compressor efficiency EC and speed ratio NLQNH (fig. 15), and overall engine performance (represented by the engine pumping characteristics (fig. 17)), did not change significantly for the two inlets. However, referred airflow rate WA1R (fig. 16) and compressor pressure ratio P3Q2 did change significantly. Each inlet produced its own engine inlet total-pressure profile, the normal UETP inlet profile showing the greater defect at the outer radius or compressor tip region (fig. 14). If it is postulated that more compressor work is done at the compressor tip than at the hub, which is the likely case for this early turbine engine design, then the compressor will be more sensitive to tip distortion; thus, more corrected airflow will be required with greater distortion. Because of the lack of instrumentation it is impossible to separate the performance of each compressor, but it is most likely that the difference in performance occurred in the first few stages of the low-pressure compressor. Thereafter, the flow adjusted itself to more uniform conditions so that the

effects of distortion were not evident for parameters associated with overall engine performance.

While there were differences in airflow rate (fig. 16), there were no significant differences in engine pumping characteristics (fig. 17), which implies that fuel flow rate adjusted to the airflow rate differences and the engine temperature rise remained virtually unchanged. This role of fuel flow rate is evidenced in the comparison of the overall engine efficiency (fig. 18), which is a function of airflow rate, fuel flow rate, and engine temperature rise. Figure 18 shows good agreement between the data of the two inlets once the engine exhaust nozzle is choked. A conclusion drawn from this is that the measurements involved are consistent; therefore, the difference shown in figure 16 for airflow rate is real.

Trends for test condition 9 were generally similar to those for test condition 6, but the data scatter due to the lower pressures prevents a good comparison. The trends for airflow rate, speed ratio, and engine pumping characteristics between the two inlets were the same as for condition 6 (table IV); but the compressor efficiency and pressure ratio trends were different.

Figure 19 is an example of why the smaller inlet duct was chosen by NASA for the UETP. There was much less scatter in the referred airflow rate data when the smaller inlet was used. It was concluded that the reason was that the Mach number at the station 1 airflow measurement station was higher and permitted a more precise measurement of total and static pressures. This is especially true in the higher speed range, where the exhaust nozzle is fully choked. At test condition 9 the difficulty in setting and stabilizing the test cell conditions resulted in an apparent contradiction below 5300 rpm.

A comparison of the turbulence levels at the engine inlet for the two inlet ducts (fig. 20) shows a decrease in turbulence with the larger inlet duct. This may be attributed to the more gradual transition from the airflow measuring station, station 1, to the engine inlet, station 2, for the larger diameter inlet duct (fig. 3).

4.2.5 Effects of nozzle exit area (A8) change. - The areas of interest in this investigation were the effect on low rotor to high rotor speed ratio, engine pumping characteristics as represented by the engine temperature rise plotted against the engine pressure rise, and referred airflow rate as a function of high and low rotor speeds. Test results are shown in figures 21 to 24. Figure 21 shows that the approximately 2-percent blockage at A8 resulted in a 1.75-percent decrease in the speed ratio NLQNH at the referred high rotor speed of 8900 rpm. In figure 22 it can be seen that there is virtually no change in the engine pumping characteristics over the entire range of engine pressure ratios. However, for referred airflow rate as plotted against referred high rotor speed (fig. 23) there is a bias shift in the data. The airflow rate for the reduced A8 was approximately 2.6 percent less than that for the normal configuration. For referred airflow rate plotted against referred low rotor speed (fig. 24) this bias shift was not apparent. There is little difference in the data for the two configurations at speeds near Military Power, but the difference increases with decreasing low rotor speed. From figures 23 and 24 it can be concluded that high rotor speed changes are nearly proportional to exhaust nozzle exit area changes, but low rotor speed changes are influenced only slightly by nozzle area changes and then only at the lower rotor speeds.

5.0 FINAL DATA PACKAGE

A summary of test results for both engines with performance normalized to standard sea-level static and desired setting conditions is presented in table V. Summary tables from the first entry (table VI) are included also. Test data will be transmitted upon request, on magnetic tapes supplied by the requesting facility, after the Working Group Chairman has approved their release.

A comparison of NASA data with data from the other UETP facilities can be found in Appendix B.

CONCLUDING REMARKS

NASA was involved in a second entry in the AGARD Uniform Engine Testing Program (UETP). With this second entry NASA documented engine deterioration that may have occurred since inception of the UETP and investigated anomalies discovered during review of data from the five facilities which had participated in the program between the two NASA entries.

1. The engines performed satisfactorily.

2. There appeared to be no significant differences in the data due to test cell variations between the two NASA entries. Therefore, the test cells should not be a factor in the engine deterioration analysis. An exception was an engine inlet temperature distortion for the lowest ram pressure condition which existed for the first entry but was minimized for the second entry.

3. There was a small change in low rotor to high rotor speed ratio of no more than 0.5 percent for both engines compared to the initial NASA entry, but there were no clear cut trends in other parameters. Therefore, it was concluded that, if engine deterioration did occur between the two NASA entries, it was not significant.

4. Tailpipe rotation showed that the measured exhaust nozzle inlet total pressure was affected by the location of the tailpipe instrumentation relative to the turbine exit struts, but the static pressure was not affected to any significant degree.

5. Inlet duct size affected station 2 total-pressure profile and certain parameters referred to engine inlet total pressure.

6. The nozzle exit area change affected the low to high rotor speed ratio and those parameters which were directly affected by high rotor speed.

APPENDIX A

SYMBOLS

A7	flow area at station 7, m^2
A8	flow area at station 8, m^2
CD8	station 8 flow coefficient based on station 1 (facility) airflow rate measurement
CG8	exhaust nozzle thrust coefficient
CV8	exhaust nozzle velocity coefficient
EC	compressor efficiency
ETA	engine efficiency
FG	facility gross thrust measurement, kN
FGR	gross thrust referred to standard sea-level static, kN
FGRD	gross thrust referred to desired conditions, kN
FN	facility net thrust measurement, kN
FNR	net thrust referred to standard sea-level static, kN
FNRD	net thrust referred to desired conditions, kN
M1	one-dimensional, ideal Mach number at station 1
NH	high-pressure compressor speed, rpm
NHR	high-pressure compressor speed referred to standard sea-level static, rpm
NHRD	high-pressure compressor speed referred to desired conditions, rpm
NL	low-pressure compressor speed, rpm
NLQNH	ratio of low-pressure compressor speed to high-pressure compressor speed
NLR	low-pressure compressor speed referred to standard sea-level static, rpm
NLRD	low-pressure compressor speed referred to desired conditions, rpm
PAMB	ambient pressure, kPa
P2, P2AV	average total pressure at station 2, kPa
P2QAMB	P2AV/PAMB

P3, P3AV	average total pressure at station 3, kPa
P3Q2	P3AV/P2AV
P5, P5AV	average total pressure at station 5, kPa
P5Q2	P5AV/P2AV
P7, P7AV	average total pressure at station 7, kPa
P7QAMB	P7AV/PAMB
P7Q2	P7AV/P2AV
PS7, PS7AV	average static pressure at station 7, kPa
PS7QAMB	PS7/PAMB
PS7Q2	PS7AV/P2AV
SFC	facility specific fuel consumption, g/kN s
SFCR	SFC referred to standard sea-level static, g/kN s
SFCRD	SFC referred to desired conditions, g/kN s
T2, T2AV	average total temperature at station 2, K
T2W	weighted total temperature at station 2, K (see fig. 5)
T5AV	average total temperature at station 5, K
T5Q2	T5AV/T2AV
T7, T7AV	average total temperature at station 7, K
T7Q2	T7AV/T2AV
TM7, TM7AV	average engine exhaust nozzle metal temperature at station 7, K
WA1	facility airflow rate measurement, kg/s
WA1R	airflow rate referred to standard sea-level static, kg/s
WA1RD	airflow rate referred to desired conditions, kg/s
WF	facility fuel flow rate measurement, g/s
WFR	fuel flow rate referred to standard sea-level static, g/s
WFRD	fuel flow rate referred to desired conditions, g/s

APPENDIX B

FACILITY COMPARISON BY BAR CHARTS

Comparisons of the performance parameters obtained in the various facilities at the operating condition for each of the test conditions as specified in the UETP General Test Plan (ref. 1) are presented in the bar charts of figures 25 to 30 and in tables VII to XII. The comparisons are presented in terms of percentage differences between the values computed from the second-order curve fits of the experimental data and the values predicted by a mathematical model for either a constant value of engine pressure ratio PS7Q2 of 1.825 (which is approximately equal to an engine total-pressure ratio of 2) (figs. 25 to 27 and tables VII to IX) or the values of referred high rotor speed NHRD specified in the General Test Plan for each test condition (figs. 28 to 30 and tables X to XII). Each of the two sets of data contain values from the nine altitude test conditions (table II) and the sea-level or equivalent condition for all the facilities. As agreed by the Working Group sponsoring the UETP, altitude data are presented only for engine S/N P-607594, while sea-level data are presented for engines S/N F-615037 and S/N P-607594.

The differences between measured and predicted parameters (figs. 25 to 30 and tables VII to XII) fell within a ±4-percent band. A large portion of the difference is due to a bias attributable to the math model not being a true representation of the UETP engines or their mode of operation during the test program. The available version of the math model was for a J57 engine, but not specifically the J57-19W engines used in the UETP. In addition the engines were not operated according to the model specifications; only one bleed was used, and the engines were derated in an effort to minimize deterioration.

More pertinent information can be obtained by comparing the maximum difference less the minimum difference, or relative difference, for each parameter without regard to facility. To further simplify the comparison, the relative differences were compared for the averaged values or the values of each parameter averaged over the range of test conditions for each facility. This produced a narrower band, as shown in figure 31 and table XIII, a comparison of these data to the math model. When this technique is used, those parameters that contain P7 have a band width of 1.8 to 3.3 percent while airflow rate has a band width of 1.6 percent and net thrust of 1.1 percent. The other parameters have band widths of less than 1 percent. The reason for the large relative differences for those parameters that contain P7 is the inability to measure an effective total pressure because of the engine exhaust nozzle inlet total-pressure distortion generated by the eight turbine exit struts, as discussed in section 4.2.3 of the main test.

The relative differences were compared for altitude conditions, test conditions 6 to 9; the band widths increased with decreasing engine inlet pressure (figs. 25 and 28). For example, the values of relative difference for WAIR increased from 1.4 percent for P2 = 82.7 kPa to 2.5 percent for P2 = 20.7 kPa. The trends were similar for the other parameters which demonstrated the increase in measurement uncertainty that occurs with decreasing pressure levels. When these values are compared with the Random Error Limit of Curve Fit (RELCF), defined as the 95-percent confidence limit of curve position (ref. 5), values for similar conditions indicate that the relative differences were larger than the RELCF for most parameters. This would indicate the existence of a bias band about the data caused by facility differences.

Figures 32 to 35 and table XIV show the RELCF value for sea level or equivalent and the averaged value for the altitude test conditions for each parameter and facility. The majority of the RELCF's are below 0.5 percent for the altitude data and 0.8 percent for the composite data (sea level or equivalent). The lower levels for the altitude data may be due, in part, to the reduction of the random component of the uncertainty by the averaging technique. But it could also indicate that the altitude facilities have more precise control of the engine environmental conditions; therefore, the data scatter is reduced. There is also an indication that operator technique, for example, the length of stabilization time, influenced the RELCF level.

REFERENCES

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2. Biesiadny, T.; Burkardt, L.; and Braithwaite, W.: Uniform Engine Testing Program, Phase I: NASA Lewis Research Center Participation. NASA TM-82978, 1982.

3. Blaha, R.J., ed.: ESCORT III Users' Manual. 2nd Edition, NASA Lewis Research Center, Sept. 1984.

4. Rudnitski, D., et al.: A Detailed Procedure for Measuring Turbojet Engine Performance in an Enclosed Sea-Level Facility. National Research Council of Canada, Technical Report LTR-ENG-120, Sept. 1983.

5. Smith, P.W.E., et al.: Final Test Report for the AGARD Uniform Engine Test Programme at RAE (Pyestock). RAE-TM-P-1059, July 1985.

TABLE I. - UETP TEST PARTICIPANTS

Order	ID	Facility	Type of test
1	NASA 1	NASA Lewis Research Center, USA	Altitude
2	AEDC	Arnold Engineering Development Center, USA	Altitude
3	NRCC 1	National Research Council, Canada	Sea level
4	CEPR	Centre d'Essais des Propulseurs, France	Sea level/ Altitude
5	TUAF	Eibmk Ligi, Turkey	Sea level
6	RAE	Royal Aircraft Establishment (Pyestock), England	Altitude
7	NASA 2 (rerun)	NASA Lewis Research Center, USA	Altitude
8	NRCC 2 (rerun)	National Research Council, Canada	Sea level
9	NAPC	Naval Air Propulsion Center, USA	Sea level

TABLE II. - TEST CONDITIONS

[High compressor speed NH corresponding to nine throttle settings listed in UETP General Test Plan (ref. 1).]

Test	Average inlet total pressure, P2AV		Ram ratio	Average inlet total temperature, T2AV, K
	kPa	psia		
[a]1	82.7	12.0	1.00	253
2				268
[a]3				288
4				308
5			1.06	288
[a,b]6			1.30	
[b]6A				
7	51.7	7.5		
8	34.5	5.0		
[a]9	20.7	3.0		
[a]10	82.7	12.0	1.70	

[a]Short test matrix.
[b]First condition run in series is repeated at end of test series.

TABLE III. - PERFORMANCE PARAMETER ERRORS

Performance parameter			Error, percent of reading		
Name	Test cell	Test condition	Bias	Precision	Uncertainty
WA1	PSL3	3	0.43	0.12	0.67
	4	3	.44	.13	.70
	3	6	.45	.11	.67
	4	6	.47	.12	.71
	3	9	1.47	.52	2.51
	4	9	1.49	.52	2.53
FN	PSL3	3	0.51	0.19	0.89
	4	3	.48	.20	.88
	3	6	.44	.20	.84
	4	6	.43	.23	.89
	3	9	1.56	.77	3.10
	4	9	1.48	.74	2.96
SFC	PSL3	3	0.81	0.35	1.51
	4	3	.74	.35	1.44
	3	6	.76	.35	1.46
	4	6	.68	.36	1.40
	3	9	1.67	.90	3.47
	4	9	1.60	.88	3.36
WA1RD	PSL3	3	0.48	0.12	0.72
	4	3	.49	.13	.75
	3	6	.50	.11	.72
	4	6	.52	.12	.76
	3	9	1.50	.52	2.54
	4	9	1.53	.52	2.57
FNRD	PSL3	3	0.37	0.17	0.71
	4	3	.36	.18	.72
	3	6	.46	.20	.86
	4	6	.44	.23	.90
	3	9	1.63	.77	3.17
	4	9	1.55	.75	3.05

TABLE III. - Continued.

Performance parameter			Error, percent of reading		
Name	Test cell	Test condition	Bias	Precision	Uncertainty
SFCRD	PSL3	3	0.75	0.34	1.43
	4	3	.70	.35	1.40
	3	6	.77	.35	1.47
	4	6	.69	.37	1.43
	3	9	1.69	.91	3.51
	4	9	1.61	.89	3.39
WFRD	PSL3	3	0.67	0.30	1.27
	4	3	.62	.30	1.22
	3	6	.67	.29	1.25
	4	6	.60	.30	1.20
	3	9	.71	.49	1.69
	4	9	.71	.50	1.71
CD8	PSL3	3	0.46	0.12	0.70
	4	3	.47	.13	.73
	3	6	.48	.12	.72
	4	6	.50	.12	.74
	3	9	1.48	.52	2.52
	4	9	1.51	.52	2.55
CG8	PSL3	3	0.36	0.17	0.70
	4	3	.35	.18	.71
	3	6	.30	.14	.58
	4	6	.30	.16	.62
	3	9	1.19	.55	2.29
	4	9	1.14	.53	2.20
CV8	PSL3	3	0.46	0.17	0.80
	4	3		.18	.82
	3	6		.15	.76
	4	6		.16	.78
	3	9	1.42	.61	2.64
	4	9	1.39	.59	2.57

TABLE III. - Concluded.

Performance parameter			Error, percent of reading		
Name	Test cell	Test condition	Bias	Precision	Uncertainty
T7Q2	PSL3	3	0.52	0.03	0.58
	4	3			
	3	6			
	4	6	↓		↓
	3	9	.55		.67
	4	9	.50	↓	.56
P7Q2	PSL3	3	0.08	0.01	0.10
	4	3			
	3	6			
	4	6	↓	↓	↓
	3	9	.33	.05	.43
	4	9	.33	.04	.41
PS7Q2	PSL3	3	0.09	0.03	0.15
	4	3	.09	.01	.11
	3	6	.10	.02	.14
	4	6	.09	.01	.11
	3	9	.32	.07	.46
	4	9	.34	.05	.44
NHRD	PSL3	3	0.21	0.02	0.25
	4	3			
	3	6			
	4	6			
	3	9			
	4	9	↓	↓	↓
NLRD	PSL3	3	0.21	0.02	0.25
	4	3			
	3	6			
	4	6			
	3	9			
	4	9	↓	↓	↓

TABLE IV. - INLET DUCT COMPARISON SHOWING CHANGES FROM UETP CONFIGURATION

[NHR = 8900 rpm.]

Test condition	Function f	Dependent variable, percent				
		EC	NLQNH	WAIR	P3Q2	T5Q2
6	f(NLR)	0.18	0.02	-0.60	-0.61	-----
	f(PS7Q2)	.18	-----	-.16	-----	-0.04
9	f(NLR)	0.43	-0.03	-0.49	-0.04	-----
	f(PS7Q2)	----	-----	-----	-----	-0.02

TABLE V. - SUMMARY OF TEST RESULTS FOR NASA ENTRY 2 IN UNIFORM ENGINE TESTING PROGRAM

(a) Engine, S/N P-607594

Test condition	Set point values			Performance normalized to sea level												
	P2AV, kPa	T2AV, K	P2QAMB	NLR, rpm	NHR, rpm	WAIR, kg/s	WFR, g/s	FGR, kN	FNR, kN	SFCR, g/kN s	NLQNH	P7QAMB	P7Q2	T7Q2	CD8	CG8
1	82.7	253	1.00	5339	8900	63.15	726.3	31.77	31.77	22.87	0.5999	1.909	1.899	2.603	0.9441	0.9343
3	82.7	288	1.00	5359		63.42	752.3	32.36	32.36	23.24	.6022	1.926	1.918	2.609	.9426	.9363
6	82.7		1.30	5410		64.56	758.1	38.04	24.84	30.49	.6079	2.499	1.909	2.594	.9617	.9540
9	20.7		1.30	5494		61.79	874.2	39.85	27.21	32.03	.6174	2.561	1.956	2.890	.9534	.9665
10	82.7		1.70	5417		64.73	757.4	42.36	23.89	31.68	.6086	3.247	1.909	2.587	.9624	.9562

Test condition	Set point values			Performance normalized to desired setting condition												
	P2AV, kPa	T2AV, K	P2QAMB	NLRD, rpm	NHRD, rpm	WAIRD, kg/s	WFRD, g/s	FGRD, kN	FNRD, kN	SFCRD, g/kN s	NLQNH	P7QAMB	P7Q2	T7Q2	CD8	CG8
1	82.7	253	1.00	5384	8675	62.02	727.0	33.795	33.795	21.52	0.6206	2.217	2.212	2.858	0.9593	0.9488
3	82.7	288	1.00	5331	8875	51.36	603.1	25.939	25.939	23.24	.6007	1.907	1.899	2.594	.9412	.9350
6	82.7		1.30	5385	8875	52.33	607.7	30.572	19.875	30.56	.6068	2.473	1.889	2.578	.9613	.9534
9	20.7		1.30	5343	8750	11.93	158.1	7.272	4.833	32.72	.6107	2.373	1.817	2.779	.9497	.9630
10	82.7		1.70	5393	8875	52.48	607.2	34.094	19.124	31.73	.6076	3.215	1.889	2.571	.9622	.9559

TABLE V. - Concluded.

(b) Engine, S/N F-615037

Test condition	Set point values			Performance normalized to sea level													
	P2AV, kPa	T2AV, K	P2QAMB	NLR, rpm	NHR, rpm	WAIR, kg/s	WFR, g/s	FGR, kN	FNR, kN	SFCR, g/kN s	NLQNH	P7QAMB	P7Q2	T7Q2	CD8	CG8
1	82.7	253	1.00	5256	8900	62.29	673.6	30.33	30.33	22.23	0.5905	1.855	1.848	2.548	0.9478	0.9361
3		288	1.00	5274		62.56	690.1	30.77	30.77	22.46	.5925	1.888	1.866	2.532	.9418	.9343
6			1.30	5334		63.92	696.0	36.49	23.42	29.77	.5994	2.341	1.798	2.510	.9935	1.0001
6A			1.30	5328		63.95	694.4	36.55	23.48	29.65	.5986	2.411	1.857	2.508	.9612	.9535
9	20.7		1.30	5417		61.20	834.8	37.61	25.10	33.19	.6086	2.445	1.887	2.808	.9634	.9602
10	82.7		1.70	5343		64.13	696.2	40.96	22.65	30.79	.6003	3.126	1.855	2.508	.9654	.9603

Test condition	Set point values			Performance normalized to desired setting condition												
	P2AV, kPa	T2AV, K	P2QAMB	NLRD, rpm	NHRD, rpm	WAIRD, kg/s	WFRD, g/s	FGRD, kN	FNRD, kN	SFCRD, g/kN s	NLQNH	P7QAMB	P7Q2	T7Q2	CD8	CG8
1	82.7	253	1.00	5424	8800	63.33	733.6	34.817	34.817	21.07	0.6164	2.259	2.249	2.872	0.9662	0.9534
3		288	1.00	5387	9000	53.01	609.5	27.199	27.199	22.42	.5985	1.968	1.947	2.594	.9470	.9394
6			1.30	5433	9000	53.92	614.5	31.883	20.862	29.43	.6037	2.446	1.878	2.578	.9960	1.0024
6A			1.30	5427	9000	53.98	614.1	31.978	20.944	29.34	.6030	2.523	1.944	2.576	.9626	.9554
9	20.7		1.30	5393	8875	12.39	167.4	7.549	5.016	33.32	.6077	2.419	1.866	2.792	.9628	.9596
10	82.7		1.70	5438	9000	54.08	615.3	35.575	20.146	30.55	.6043	3.274	1.942	2.578	.9656	.9611

TABLE VI. - SUMMARY OF TEST RESULTS FOR NASA ENTRY 1 IN UNIFORM ENGINE TESTING PROGRAM

(a) Engine, S/N P-607594

Test condition	Set point values			Performance normalized to sea level												
	P2AV, kPa	T2AV, K	P2QAMB	NLR, rpm	NHR, rpm	WAIR, kg/s	WFR, g/s	FGR, kN	FNR, kN	SFCR, g/kN s	NLQNH	P7QAMB	P7Q2	T7Q2	CD8	CG8
1	82.7	253	1.00	5373	8900	65.2	736	32.9	32.9	22.4	0.604	1.936	1.935	2.601	0.969	0.949
2		268	1.00	5381		65.3	746	33.2	33.2	22.5	.605	1.946	1.944	2.605	.965	.946
4		308	1.00	5397		65.1	761	33.3	33.3	22.8	.606	1.952	1.950	2.605	.946	.932
5		288	1.06	5409		65.3	749	36.6	28.1	26.7	.608	2.037	1.895	2.574	.975	.977
6			1.30	5433		65.5	747	43.1	25.1	29.7	.610	2.462	1.886	2.563	.980	.982
6A				5425		65.3	742	42.8	24.9	29.8	.610	2.491	1.912	2.590	.970	.957
7	51.7			5454		65.0	774	43.3	25.5	30.3	.613	2.509	1.938	2.654	.964	.951
8	34.5			5479		64.2	812	43.5	25.9	31.2	.616	2.496	1.945	2.739	.965	.951
9	20.7			5515		62.7	885	43.8	26.6	33.2	.620	2.552	1.957	2.895	.966	.951
10	82.7		1.70	5435		65.4	745	49.2	24.1	30.8	.611	3.167	1.877	2.558	.982	.987

Test condition	Set point values			Performance normalized to desired setting condition												
	P2AV, kPa	T2AV, K	P2QAMB	NLRD, rpm	NHRD, rpm	WAIRD, kg/s	WFRD, g/s	FGRD, kN	FNRD, kN	SFCRD, g/kN s	NLQNH	P7QAMB	P7Q2	T7Q2	CD8	CG8
1	82.7	253	1.00	5418	8675	63.9	742	34.8	34.8	21.3	0.625	2.249	2.254	2.855	0.969	0.949
2		268	1.00	5412	8775	59.3	688	31.5	31.5	21.8	.617	2.120	2.120	2.742	.965	.946
4		308	1.00	5432	9075	49.1	581	24.6	24.6	23.6	.599	1.850	1.847	2.526	.946	.931
5		288	1.06	5383	8875	53.0	600	27.7	22.5	26.7	.607	2.017	1.876	2.559	.974	.976
6			1.30	5408	8875	53.1	598	30.9	20.1	29.8	.609	2.437	1.867	2.547	.980	.981
6A				5400	8875	52.9	595	30.8	19.9	29.8	.608	2.465	1.892	2.574	.969	.957
7	51.7			5455	8900	33.2	395	19.8	13.0	30.3	.613	2.512	1.941	2.655	.964	.950
8	34.5			5405	8825	21.3	260	12.6	8.2	31.5	.612	2.412	1.878	2.686	.965	.951
9	20.7			5365	8750	12.1	161	7.2	4.7	34.1	.613	2.377	1.820	2.789	.965	.949
10	82.7		1.70	5411	8875	53.0	597	34.4	19.3	30.9	.610	3.134	1.857	2.542	.983	.987

TABLE VI. - Concluded.

(b) Engine, S/N F-615037

Test condition	Set point values			Performance normalized to sea level												
	P2AV, kPa	T2AV, K	P2QAMB	NLR, rpm	NHR, rpm	WAIR, kg/s	WFR, g/s	FGR, kN	FNR, kN	SFCR, g/kN s	NLQNH	P7QAMB	P7Q2	T7Q2	CD8	CG8
1	82.7	253	1.00	5304	8900	63.9	703	31.7	31.7	22.2	0.596	1.901	1.892	2.579	0.969	0.954
2		268		5311		64.1	710	31.9	31.9	22.3	.597	1.906	1.896	2.578	.968	.953
3		288		5302		63.6	706	31.6	31.6	22.4	.596	1.892	1.887	2.536	.955	.946
4		308		5309		63.5	712	31.6	31.6	22.5	.597	1.897	1.890	2.541	.948	.940
5		288	1.06	5319		63.8	704	35.0	26.6	26.5	.598	2.006	1.887	2.538	.955	.944
6			1.30	5363		64.5	710	41.7	24.0	29.7	.603	2.445	1.880	2.536	.964	.954
6A				5353		64.3	705	41.5	23.9	29.6	.601	2.459	1.878	2.525	.961	.952
7	51.7			5387		64.0	735	42.0	24.4	30.2	.605	2.450	1.881	2.586	.967	.962
8	34.5			5414		63.4	773	42.1	24.7	31.3	.608	2.421	1.897	2.701	.971	.956
9	20.7			5443		61.6	836	42.2	25.3	33.0	.612	2.478	1.903	2.829	.965	.956
10	82.7		1.70	5369		64.6	710	47.9	23.2	30.7	.603	3.204	1.878	2.534	.965	.960

Test condition	Set point values			Performance normalized to desired setting condition												
	P2AV, kPa	T2AV, K	P2QAMB	NLRD, rpm	NHRD, rpm	WAIRD, kg/s	WFRD, g/s	FGRD, kN	FNRD, kN	SFCRD, g/kN s	NLQNH	P7QAMB	P7Q2	T7Q2	CD8	CG8
1	82.7	253	1.00	5469	8800	64.6	764	36.0	36.0	21.2	0.621	2.301	2.295	2.905	0.971	0.955
2		268		5494	8925	60.7	725	33.4	33.4	21.7	.616	2.196	2.187	2.808	.969	.954
3		288		5415	9000	53.8	623	27.8	27.8	22.4	.602	1.975	1.968	2.602	.953	.944
4		308		5488	9200	50.1	601	25.8	25.8	23.3	.596	1.896	1.889	2.540	.946	.938
5		288	1.06	5427	9000	53.9	623	28.9	23.7	26.3	.603	2.095	1.971	2.603	.953	.942
6			1.30	5462	9000	54.4	627	32.5	21.3	29.4	.607	2.557	1.967	2.606	.964	.954
6A				5453	9000	54.3	623	32.4	21.3	29.3	.606	2.573	1.965	2.594	.961	.952
7	51.7			5413	8925	33.0	383	19.5	12.8	30.1	.606	2.481	1.905	2.605	.967	.961
8	34.5			5440	8925	21.8	269	13.1	8.6	31.1	.610	2.452	1.921	2.720	.970	.954
9	20.7			5420	8875	12.5	168	7.6	5.1	33.2	.611	2.450	1.882	2.813	.964	.954
10	82.7		1.70	5466	9000	54.4	627	36.1	20.5	30.5	.607	3.356	1.965	2.603	.965	.960

TABLE VII. - UETP ALTITUDE FACILITY COMPARISON

[Engine, S/N P-607594; reference, math model; independent variable, PS7Q2 = 1.8251.]

(a) Test condition, 1(82.7-1.0-253)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAIR	67.002	65.992	66.861	65.676	66.242	1.148	-0.377	0.935	-0.854
2 WFR	779.324	775.493	782.143	784.574	778.663	0.085	-0.407	0.447	0.759
3 FNR	34.915	35.203	35.428	35.256	35.121	-0.588	0.233	0.875	0.384
4 SFCR	22.343	22.051	22.085	22.282	22.171	0.775	-0.539	-0.388	0.499
5 P7Q2	2.001	2.012	1.983	2.008	2.000	0.061	0.585	-0.854	0.378
6 T7Q2	2.653	2.666	2.692	2.691	2.674	-0.794	-0.297	0.678	0.637
7 P7/pa	2.000	2.027	1.992	2.042	2.000	-0.006	1.359	-0.407	2.102
8 NL/NH	0.608	0.608	0.609	0.608	0.608	0.093	0.010	0.125	0.088
9 CD8	0.961	0.944	0.975	0.947	0.956	0.438	-1.297	1.925	-0.972
10 CG8	0.940	0.940	0.969	0.946	0.958	-1.907	-1.857	1.126	-1.291
11 ETA	0.992	0.991	1.010	0.991	0.995	-0.335	-0.445	1.522	-0.418
12 NHR/100	89.730	89.722	90.357	90.198	90.053	-0.359	-0.367	0.338	0.161
13 NLR/100	54.589	54.540	54.988	54.871	54.735	-0.266	-0.356	0.463	0.250
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825	0.000	0.000	0.000	0.000

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(b) Test condition, 2(82.7-1.0-268)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAIR	66.925	65.946	66.711	65.609	66.242	1.031	-0.446	0.708	-0.955
2 WFR	783.627	777.881	787.470	789.298	787.361	-0.474	-1.204	0.014	0.246
3 FNR	34.962	35.244	35.504	35.268	35.121	-0.452	0.349	1.091	0.418
4 SFCR	22.431	22.093	22.168	22.392	22.418	0.055	-1.452	-1.118	-0.117
5 P7Q2	2.001	2.010	1.981	2.004	2.000	0.070	0.479	-0.938	0.214
6 T7Q2	2.650	2.664	2.685	2.684	2.674	-0.896	-0.367	0.423	0.374
7 P7/pa	2.003	2.018	1.985	2.037	2.000	0.160	0.880	-0.733	1.839
8 NL/NH	0.609	0.608	0.608	0.609	0.608	0.163	-0.015	0.099	0.182
9 CD8	0.960	0.945	0.973	0.947	0.956	0.334	-1.203	1.695	-0.990
10 CG8	0.941	0.943	0.972	0.949	0.958	-1.776	-1.577	1.466	-0.996
11 ETA	0.994	0.996	1.008	0.990	0.995	-0.092	0.101	1.306	-0.484
12 NHR/100	89.650	89.726	90.309	90.115	90.053	-0.447	-0.362	0.285	0.069
13 NLR/100	54.579	54.528	54.945	54.872	54.735	-0.285	-0.377	0.384	0.251
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825	0.000	0.000	0.000	0.000

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TABLE VII. - Continued.

(c) Test condition for AEDC, CEPR, and RAE, 3(82.7-1.0-288); test condition for NASA 1, 4(82.7-1.0-308)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAIR	66.580	65.883	66.410	65.468	66.242	0.511	-0.541	0.255	-1.168
2 WFR	797.231	785.513	794.359	789.907	797.547	-0.040	-1.509	-0.400	-0.958
3 FNR	35.030	35.342	35.563	34.938	35.121	-0.259	0.630	1.259	-0.521
4 SFCR	22.741	22.210	22.248	22.583	22.708	0.142	-2.195	-2.028	-0.553
5 P7Q2	2.005	2.009	1.978	2.001	2.000	0.271	0.451	-1.082	0.045
6 T7Q2	2.648	2.666	2.676	2.679	2.674	-0.979	-0.316	0.061	0.199
7 P7/pa	2.008	2.015	1.985	2.032	2.000	0.399	0.727	-0.772	1.579
8 NL/NH	0.610	0.608	0.611	0.609	0.608	0.373	0.099	0.444	0.204
9 CD8	0.955	0.945	0.964	0.946	0.957	-0.196	-1.211	0.794	-1.089
10 CG8	0.940	0.946	0.975	0.942	0.958	-1.888	-1.296	1.714	-1.670
11 ETA	0.984	0.999	1.002	0.996	0.995	-1.068	0.388	0.699	0.127
12 NHR/100	89.645	89.798	90.466	89.960	90.053	-0.453	-0.283	0.459	-0.103
13 NLR/100	54.690	54.634	55.230	54.790	54.735	-0.081	-0.184	0.905	0.100
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825	0.000	0.000	0.000	0.000

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(d) Test condition, 4(82.7-1.0-308)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAIR	66.580	65.889	66.463	65.236	65.374	1.846	0.789	1.667	-0.211
2 WFR	797.231	791.106	802.488	788.422	783.301	1.778	0.996	2.450	0.654
3 FNR	35.030	35.302	35.562	34.574	35.075	-0.128	0.646	1.390	-1.429
4 SFCR	22.741	22.395	22.603	22.793	22.332	1.829	0.283	1.213	2.063
5 P7Q2	2.005	2.007	1.976	1.994	2.000	0.271	0.350	-1.213	-0.323
6 T7Q2	2.648	2.659	2.665	2.648	2.650	-0.072	0.355	0.590	-0.084
7 P7/pa	2.008	2.016	1.987	2.001	2.000	0.399	0.786	-0.629	0.046
8 NL/NH	0.610	0.608	0.609	0.608	0.605	0.766	0.432	0.527	0.444
9 CD8	0.955	0.946	0.971	0.942	0.940	1.606	0.722	3.347	0.268
10 CG8	0.940	0.947	0.978	0.938	0.957	-1.747	-1.072	2.232	-1.976
11 ETA	0.994	0.999	0.997	0.986	0.995	-0.052	0.383	0.241	-0.920
12 NHR/100	89.645	89.772	90.423	89.695	89.688	-0.049	0.093	0.819	0.007
13 NLR/100	54.690	54.587	55.034	54.546	54.301	0.717	0.526	1.351	0.452
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825	0.000	0.000	0.000	0.000

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TABLE VII. - Continued.

(e) Test condition, 6(82.7-1.3-288)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAIR	67.508	67.019	67.590	66.622	66.818	1.033	0.301	1.156	-0.293
2 WFR	803.597	798.162	809.444	809.343	810.424	-0.842	-1.513	-0.121	-0.133
3 FNR	27.279	27.517	27.780	27.673	27.109	0.626	1.503	2.476	2.078
4 SFCR	29.378	28.952	29.056	29.172	29.895	-1.729	-3.154	-2.806	-2.417
5 P7Q2	2.005	2.016	1.983	2.016	2.000	0.251	0.791	-0.870	0.821
6 T7Q2	2.666	2.674	2.680	2.682	2.685	-0.727	-0.426	-0.211	-0.108
7 P7/pa	2.614	2.640	2.543	2.624	2.600	0.525	1.550	-2.192	0.918
8 NL/NH	0.614	0.614	0.614	0.613	0.609	0.832	0.824	0.813	0.640
9 CD8	0.971	0.960	0.985	0.957	0.967	0.395	-0.688	1.838	-1.019
10 CG8	0.959	0.955	0.987	0.957	0.966	-0.729	-1.106	2.136	-0.925
11 ETA	1.000	1.005	1.003	0.992	0.995	0.543	0.987	0.825	-0.314
12 NHR/100	90.063	90.037	90.610	90.297	90.296	-0.258	-0.287	0.348	0.000
13 NLR/100	55.335	55.314	55.660	55.373	55.020	0.572	0.535	1.164	0.641
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825	0.000	0.000	0.000	0.000

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(f) Test condition, 7(51.7-1.3-288)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAIR	66.837	66.053	67.094	65.861	65.710	1.716	0.523	2.106	0.230
2 WFR	825.379	820.897	832.602	826.267	813.779	1.425	0.875	2.313	1.535
3 FNR	27.487	27.575	27.964	27.637	27.684	-0.713	-0.393	1.012	-0.171
4 SFCR	29.990	29.722	29.686	29.833	29.395	2.024	1.113	0.989	1.491
5 P7Q2	2.017	2.020	1.982	2.015	2.000	0.855	1.004	-0.922	0.735
6 T7Q2	2.715	2.722	2.725	2.734	2.717	-0.045	0.197	0.310	0.651
7 P7/pa	2.611	2.644	2.563	2.620	2.600	0.412	1.675	-1.427	0.751
8 NL/NH	0.617	0.616	0.616	0.615	0.608	1.468	1.370	1.278	1.168
9 CD8	0.965	0.953	0.987	0.957	0.957	0.829	-0.424	3.158	-0.024
10 CG8	0.952	0.948	0.990	0.954	0.974	-2.281	-2.681	1.549	-2.140
11 ETA	0.996	0.994	0.998	0.993	0.994	0.192	-0.004	0.309	-0.153
12 NHR/100	89.862	89.998	90.556	90.110	90.053	-0.211	-0.061	0.559	0.063
13 NLR/100	55.421	55.451	55.744	55.409	54.735	1.254	1.308	1.843	1.232
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825	0.000	0.000	0.000	0.000

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TABLE VII. - Continued.

(g) Test condition, 8(34.5-1.3-288)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAIR	65.821	64.899	66.748	65.173	66.502	-1.024	-2.411	0.370	-1.999
2 WFR	857.055	851.378	858.011	868.667	879.406	-2.542	-3.187	-2.433	-1.221
3 FNR	27.664	27.571	27.668	28.116	27.666	-0.006	-0.341	0.007	1.628
4 SFCR	30.875	30.764	30.897	30.761	31.787	-2.870	-3.219	-2.798	-3.227
5 P7Q2	2.013	2.019	1.977	2.029	2.000	0.672	0.936	-1.167	1.428
6 T7Q2	2.794	2.801	2.774	2.822	2.806	-0.420	-0.175	-1.149	0.576
7 P7/pa	2.582	2.643	2.560	2.636	2.600	-0.708	1.658	-1.522	1.370
8 NL/NH	0.619	0.618	0.616	0.618	0.609	1.679	1.617	1.189	1.472
9 CD8	0.967	0.952	0.996	0.957	0.985	-1.823	-3.297	1.120	-2.832
10 CG8	0.954	0.945	0.985	0.953	0.978	-2.435	-3.395	0.739	-2.584
11 ETA	0.993	0.990	0.993	0.987	0.985	0.768	0.465	0.800	0.170
12 NHR/100	89.732	89.921	90.125	90.163	90.174	-0.490	-0.280	-0.054	-0.012
13 NLR/100	55.526	55.609	55.500	55.678	54.878	1.181	1.332	1.134	1.459
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825	0.000	0.000	0.000	0.000

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(h) Test condition, 9(20.7-1.3-288)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAIR	64.057	63.027	62.488	62.792	63.502	0.873	-0.748	-1.597	-1.119
2 WFR	920.699	917.660	907.373	922.907	922.362	-0.180	-0.510	-1.625	0.059
3 FNR	27.972	27.453	27.490	28.093	27.401	2.084	0.190	0.325	2.528
4 SFCR	32.802	33.346	32.920	32.778	33.662	-2.554	-0.938	-2.204	-2.624
5 P7Q2	2.013	2.017	1.970	2.014	2.000	0.645	0.848	-1.485	0.700
6 T7Q2	2.937	2.949	2.900	2.951	2.930	0.214	0.622	-1.055	0.700
7 P7/pa	2.623	2.652	2.553	2.620	2.600	0.887	2.003	-1.820	0.751
8 NL/NH	0.622	0.621	0.619	0.620	0.618	0.622	0.509	0.072	0.290
9 CD8	0.967	0.952	0.956	0.951	0.962	0.581	-1.046	-0.591	-1.125
10 CG8	0.955	0.935	0.964	0.951	0.958	-0.343	-2.409	0.646	-0.719
11 ETA	0.979	0.973	0.951	0.966	0.966	1.305	0.724	-1.572	-0.035
12 NHR/100	89.575	89.827	89.792	89.842	89.797	-0.247	0.032	-0.006	0.049
13 NLR/100	55.718	55.811	55.547	55.699	55.511	0.373	0.542	0.066	0.339
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825	0.000	0.000	0.000	0.000

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TABLE VII. - Concluded.

(i) Test condition, 10(82.7-1.7-288)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAIR	67.504	66.923	67.678	66.636	66.530	1.464	0.592	1.726	0.160
2 WFR	803.526	799.606	812.016	807.826	798.134	0.676	0.184	1.739	1.214
3 FNR	26.237	26.383	26.774	26.611	26.260	-0.086	0.469	1.960	1.336
4 SFCR	30.562	30.257	30.236	30.284	30.394	0.553	-0.451	-0.517	-0.360
5 P7Q2	1.967	2.017	1.984	2.013	2.000	-1.653	0.842	-0.821	0.665
6 T7Q2	2.630	2.671	2.683	2.681	2.669	-1.440	0.080	0.526	0.472
7 P7/pa	3.319	3.454	3.356	3.436	3.400	-2.371	1.578	-1.285	1.046
8 NL/NH	0.615	0.615	0.614	0.614	0.609	1.084	1.008	0.927	0.817
9 CD8	0.982	0.958	0.986	0.958	0.960	2.325	-0.235	2.725	-0.152
10 CG8	0.987	0.956	0.989	0.961	0.972	1.570	-1.656	1.781	-1.068
11 ETA	0.979	1.000	1.003	0.993	0.995	-1.605	0.501	0.832	-0.197
12 NHR/100	90.007	90.062	90.747	90.278	90.174	-0.186	-0.125	0.635	0.115
13 NLR/100	55.370	55.362	55.738	55.389	54.878	0.896	0.882	1.568	0.932
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825	0.000	0.000	0.000	0.000

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TABLE VIII. - SEA-LEVEL FACILITY COMPARISON

[Reference, math model; independent variable, PS7Q2 = 1.8251; test condition, sea level (101.3-1.0-288).]

(a) Engine, S/N F-615037

	Actual values			Percent, differences from reference			
	NRCC 1	CEPR	TUAF	REF	DIF-C	DIF-F	DIF-T
1 WAIR	65.679	67.172	67.417	66.580	-1.353	0.889	1.258
2 WFR	773.966	775.746	773.983	764.906	1.185	1.417	1.187
3 FNR	34.681	35.185	34.318	34.385	0.860	2.328	-0.197
4 SFCR	22.295	22.092	22.514	22.245	0.221	-0.690	1.207
5 P7Q2	1.984	1.990	2.004	2.000	-0.786	-0.478	0.195
6 T7Q2	2.589	2.623	2.560	2.604	-0.575	0.708	-1.688
7 P7/pa	1.994	2.018	2.004	2.000	-0.293	0.898	0.217
8 NL/NH	0.603	0.601	0.603	0.609	-1.007	-1.259	-0.968
9 CD8	0.938	0.963	0.945	0.948	-1.119	1.592	-0.338
10 CG8	0.947	0.957	0.920	0.938	1.009	2.020	-1.936
11 ETA	0.963	1.002	0.968	0.995	-3.186	0.676	-2.675
12 NHR/100	90.639	90.963	89.803	90.195	0.492	0.851	-0.435
13 NLR/100	54.617	54.673	54.135	54.902	-0.520	-0.418	-1.399
14 Ps7/P2	1.825	1.825	1.825	1.825	0.000	0.000	0.000

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(b) Engine, S/N P-607594

	Actual values		Percent, differences from reference		
	NRCC 1	CEPR	REF	DIF-C	DIF-F
1 WAIR	65.283	66.815	65.374	-0.139	2.205
2 WFR	788.046	779.466	779.601	1.083	-0.017
3 FNR	34.739	35.008	34.900	-0.462	0.309
4 SFCR	22.673	22.265	22.338	1.501	-0.328
5 P7Q2	2.007	1.982	2.000	0.364	-0.884
6 T7Q2	2.638	2.645	2.660	-0.820	-0.536
7 P7/pa	2.018	2.012	2.000	0.883	0.591
8 NL/NH	0.609	0.608	0.605	0.591	0.397
9 CD8	0.931	0.967	0.941	-1.108	2.771
10 CG8	0.931	0.959	0.952	-2.182	0.749
11 ETA	0.971	1.006	0.995	-2.397	1.143
12 NHR/100	89.999	90.102	89.688	0.347	0.461
13 NLR/100	54.812	54.768	54.301	0.940	0.860
14 Ps7/P2	1.825	1.825	1.825	0.000	0.000

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TABLE IX. - COMPARISON AT SEA-LEVEL OR EQUIVALENT FOR ALL FACILITIES

[Reference, math model; independent variable, PS7Q2 = 1.8251.]

(a) Engine, S/N F-615037; test condition for AEDC, NRCC 1, CEPR, and TUAF, sea level (101.3-1.0-288); test condition for NASA 1, 3(82.7-1.0-288)

	Actual values				
	NASA 1	AEDC	NRCC 1	CEPR	TUAF
1 WAIR	66.566	66.208	65.679	67.172	67.417
2 WFR	777.126	772.805	773.966	775.746	773.983
3 FNR	34.836	35.226	34.681	35.185	34.318
4 SFCR	22.297	21.921	22.295	22.092	22.514
5 P7Q2	1.992	2.004	1.984	1.990	2.004
6 T7Q2	2.622	2.625	2.589	2.623	2.560
7 P7/pa	1.999	2.015	1.994	2.018	2.004
8 NL/NH	0.603	0.602	0.603	0.601	0.603
9 CD8	0.954	0.944	0.938	0.963	0.945
10 CG8	0.945	0.946	0.947	0.957	0.920
11 ETA	0.991	0.994	0.963	1.002	0.968
12 NHR/100	90.322	90.460	90.639	90.963	89.803
13 NLR/100	54.487	54.442	54.617	54.673	54.135
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825

	Percent, differences from reference					
	REF	DIF-L	DIF-A	DIF-C	DIF-F	DIF-T
1 WAIR	66.580	-0.020	-0.559	-1.353	0.889	1.258
2 WFR	764.906	1.598	1.033	1.185	1.417	1.187
3 FNR	34.385	1.312	2.445	0.860	2.328	-0.197
4 SFCR	22.245	0.234	-1.456	0.221	-0.690	1.207
5 P7Q2	2.000	-0.392	0.220	-0.786	-0.478	0.195
6 T7Q2	2.604	0.662	0.806	-0.575	0.708	-1.688
7 P7/pa	2.000	-0.035	0.758	-0.293	0.898	0.217
8 NL/NH	0.609	-0.896	-1.129	-1.007	-1.259	-0.968
9 CD8	0.948	0.618	-0.444	-1.119	1.592	-0.338
10 CG8	0.938	0.729	0.918	1.009	2.020	-1.936
11 ETA	0.995	-0.383	-0.135	-3.186	0.676	-2.675
12 NHR/100	90.195	0.140	0.293	0.492	0.851	-0.435
13 NLR/100	54.902	-0.757	-0.839	-0.520	-0.418	-1.399
14 Ps7/P2	1.825	0.000	0.000	0.000	0.000	0.000

TABLE IX. - Concluded.

(b) Engine, S/N P-607594; test condition for AEDC, NRCC 1, CEPR, and RAE, sea level (101.3-1.0-288); test condition for NASA 1, 4(82.7-1.0-308)

	Actual values				
	NASA 1	AEDC	NRCC 1	CEPR	RAE
1 WAIR	66.580	66.032	65.283	66.815	65.468
2 WFR	797.231	780.212	788.046	779.466	789.907
3 FNR	35.030	35.344	34.739	35.008	34.938
4 SFCR	22.741	22.058	22.673	22.265	22.583
5 P7Q2	2.005	2.009	2.007	1.982	2.001
6 T7Q2	2.648	2.655	2.638	2.645	2.679
7 P7/pa	2.008	2.018	2.018	2.012	2.032
8 NL/NH	0.610	0.608	0.609	0.608	0.609
9 CD8	0.955	0.945	0.931	0.967	0.946
10 CG8	0.940	0.946	0.931	0.959	0.942
11 ETA	0.984	1.001	0.971	1.006	0.996
12 NHR/100	89.645	89.833	89.999	90.102	89.960
13 NLR/100	54.690	54.600	54.812	54.768	54.790
14 Ps7/P2	1.825	1.825	1.825	1.825	1.825

	Percent, differences from reference					
	REF	DIF-L	DIF-A	DIF-C	DIF-F	DIF-R
1 WAIR	65.374	1.846	1.006	-0.139	2.205	0.144
2 WFR	779.601	2.261	0.078	1.083	-0.017	1.322
3 FNR	34.900	0.372	1.270	-0.462	0.309	0.108
4 SFCR	22.338	1.803	-1.254	1.501	-0.328	1.097
5 P7Q2	2.000	0.271	0.435	0.364	-0.884	0.045
6 T7Q2	2.660	-0.439	-0.162	-0.820	-0.536	0.745
7 P7/pa	2.000	0.399	0.908	0.883	0.591	1.579
8 NL/NH	0.605	0.766	0.389	0.591	0.397	0.596
9 CD8	0.941	1.416	0.411	-1.108	2.771	0.509
10 CG8	0.952	-1.260	-0.636	-2.182	0.749	-1.041
11 ETA	0.995	-1.068	0.584	-2.397	1.143	0.127
12 NHR/100	89.688	-0.049	0.161	0.347	0.461	0.302
13 NLR/100	54.301	0.717	0.551	0.940	0.860	0.900
14 Ps7/P2	1.825	0.000	0.000	0.000	0.000	0.000

TABLE X. - UETP ALTITUDE FACILITY COMPARISON

[Reference, math model; engine, S/N P-607594; independent variable, NHRD.]

(a) NHRD, 8675; test condition, 1(82.7-1.0-253)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAID	63.875	62.847	62.434	61.796	62.751	1.791	0.153	-0.505	-1.522
2 WFD	738.765	732.908	708.905	717.322	719.215	2.718	1.904	-1.434	-0.263
3 FND	34.774	35.084	33.876	34.040	34.159	1.799	2.707	-0.831	-0.350
4 SFCD	21.230	20.883	20.903	21.066	21.055	0.831	-0.816	-0.722	0.053
5 P7Q2	2.254	2.265	2.176	2.217	2.224	1.354	1.846	-2.151	-0.318
6 T7Q2	2.855	2.869	2.845	2.860	2.838	0.573	1.074	0.228	0.758
7 P7/pa	2.249	2.283	2.186	2.255	2.224	1.102	2.646	-1.703	1.376
8 NL/NH	0.625	0.623	0.622	0.621	0.621	0.556	0.388	0.103	0.064
9 CD8	0.969	0.952	0.979	0.956	0.965	0.493	-1.273	1.460	-0.898
10 CG8	0.949	0.951	0.976	0.954	0.964	-1.524	-1.294	1.316	-0.949
11 ETA	0.996	0.996	1.007	0.995	0.995	0.070	0.089	1.203	0.025
12 NHD/100	86.750	86.750	86.750	86.750	86.750	0.000	0.000	0.000	0.000
13 NLD/100	54.178	54.087	53.934	53.913	53.878	0.556	0.388	0.103	0.064
14 Ps7/P2	2.053	2.052	2.002	2.012	2.030	1.140	1.098	-1.374	-0.868

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(b) NHRD, 8775; test condition, 2(82.7-1.0-268)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAID	59.274	58.175	57.760	57.178	57.930	2.319	0.422	-0.295	-1.299
2 WFD	684.592	674.141	653.502	664.268	666.350	2.738	1.169	-1.928	-0.312
3 FND	31.506	31.541	30.480	30.681	30.713	2.581	2.698	-0.759	-0.103
4 SFCD	21.719	21.364	21.412	21.642	21.696	0.105	-1.530	-1.310	-0.252
5 P7Q2	2.120	2.119	2.039	2.079	2.084	1.725	1.673	-2.174	-0.231
6 T7Q2	2.742	2.751	2.732	2.744	2.735	0.278	0.574	-0.110	0.338
7 P7/pa	2.120	2.127	2.043	2.112	2.084	1.739	2.076	-1.977	1.373
8 NL/NH	0.617	0.615	0.613	0.614	0.613	0.553	0.259	-0.138	0.090
9 CD8	0.965	0.949	0.975	0.951	0.960	0.535	-1.061	1.630	-0.930
10 CG8	0.946	0.949	0.975	0.952	0.960	-1.429	-1.157	1.580	-0.814
11 ETA	0.996	0.997	1.008	0.991	0.995	0.072	0.235	1.327	-0.362
12 NHD/100	87.750	87.750	87.750	87.750	87.750	0.000	0.000	0.000	0.000
13 NLD/100	54.121	53.963	53.749	53.871	53.823	0.553	0.259	-0.138	0.090
14 Ps7/P2	1.931	1.922	1.877	1.892	1.902	1.556	1.092	-1.273	-0.511

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TABLE X. - Continued.

(c) NHRD, 8875; test condition for AEDC, CEPR, and RAE, 3(82.7-1.0-288); test condition for NASA 1, 4(82.7-1.0-308)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAID	52.741	51.878	51.115	51.228	51.571	2.269	0.596	-0.885	-0.664
2 WFD	606.951	590.754	566.116	585.983	586.695	3.452	0.692	-3.508	-0.121
3 FND	26.714	26.627	25.368	25.962	25.871	3.260	2.923	-1.943	0.354
4 SFCD	22.699	22.197	22.266	22.572	22.678	0.091	-2.122	-1.816	-0.466
5 P7Q2	1.930	1.922	1.839	1.900	1.884	2.459	2.022	-2.369	0.874
6 T7Q2	2.590	2.598	2.566	2.600	2.591	-0.030	0.278	-0.962	0.356
7 P7/pa	1.932	1.927	1.844	1.930	1.884	2.577	2.296	-2.098	2.441
8 NL/NH	0.605	0.602	0.600	0.602	0.599	1.002	0.535	0.207	0.510
9 CD8	0.951	0.940	0.959	0.940	0.952	-0.144	-1.260	0.732	-1.280
10 CG8	0.936	0.940	0.966	0.936	0.956	-2.096	-1.650	1.052	-2.121
11 ETA	0.984	0.999	1.003	0.996	0.995	-1.082	0.370	0.851	0.088
12 NHD/100	88.750	88.750	88.750	88.750	88.750	0.000	0.000	0.000	0.000
13 NLD/100	53.693	53.445	53.270	53.431	53.160	1.002	0.535	0.207	0.510
14 Ps7/P2	1.758	1.747	1.699	1.731	1.719	2.277	1.640	-1.186	0.693

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(d) NHRD, 9075; test condition, 4(82.7-1.0-308)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAID	49.136	48.344	47.914	47.874	47.911	2.558	0.905	0.007	-0.076
2 WFD	578.022	567.452	552.315	568.037	563.304	2.613	0.736	-1.951	0.840
3 FND	24.601	24.519	23.740	24.035	24.436	0.674	0.338	-2.850	-1.641
4 SFCD	23.489	23.150	23.206	23.629	23.052	1.895	0.425	0.669	2.504
5 P7Q2	1.847	1.839	1.773	1.830	1.825	1.206	0.739	-2.855	0.282
6 T7Q2	2.526	2.532	2.505	2.526	2.526	0.012	0.244	-0.831	0.006
7 P7/pa	1.850	1.846	1.784	1.837	1.825	1.343	1.163	-2.226	0.657
8 NL/NH	0.599	0.596	0.595	0.596	0.591	1.264	0.843	0.716	0.899
9 CD8	0.946	0.936	0.954	0.931	0.932	1.478	0.447	2.405	-0.107
10 CG8	0.931	0.936	0.967	0.925	0.954	-2.461	-1.961	1.305	-3.038
11 ETA	0.995	1.001	0.999	0.987	0.995	-0.025	0.560	0.420	-0.817
12 NHD/100	90.750	90.750	90.750	90.750	90.750	0.000	0.000	0.000	0.000
13 NLD/100	54.324	54.098	54.030	54.128	53.646	1.264	0.843	0.716	0.899
14 Ps7/P2	1.685	1.676	1.641	1.674	1.665	1.157	0.627	-1.465	0.487

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TABLE X. - Continued.

(e) NHRD 8875; test condition, 6(82.7-1.3-288)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAID	52.915	52.435	52.114	51.755	51.571	2.607	1.675	1.052	0.357
2 WFD	592.023	588.976	572.306	584.405	584.821	1.232	0.711	-2.140	-0.071
3 FND	19.936	20.149	19.375	19.803	19.410	2.714	3.809	-0.176	2.026
4 SFCD	29.691	29.250	29.548	29.519	30.131	-1.458	-2.922	-1.932	-2.029
5 P7Q2	1.892	1.903	1.828	1.881	1.862	1.599	2.231	-1.845	1.043
6 T7Q2	2.574	2.585	2.553	2.573	2.586	-0.491	-0.047	-1.282	-0.512
7 P7/pa	2.465	2.493	2.341	2.449	2.420	1.845	3.000	-3.300	1.159
8 NL/NH	0.608	0.608	0.606	0.606	0.599	1.576	1.581	1.198	1.207
9 CD8	0.969	0.957	0.983	0.955	0.963	0.684	-0.601	2.144	-0.835
10 CG8	0.957	0.952	0.983	0.954	0.965	-0.834	-1.328	1.897	-1.114
11 ETA	0.999	1.003	1.003	0.991	0.995	0.421	0.791	0.793	-0.447
12 NHD/100	88.750	88.750	88.750	88.750	88.750	0.000	0.000	0.000	0.000
13 NLD/100	53.998	54.001	53.797	53.802	53.160	1.576	1.581	1.198	1.207
14 Ps7/P2	1.722	1.723	1.682	1.702	1.699	1.336	1.406	-1.024	0.187

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(f) NHRD, 8900; test condition, 7(51.7-1.3-288)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAID	33.188	32.631	32.630	32.413	32.280	2.811	1.086	1.082	0.411
2 WFD	393.724	387.660	376.450	386.344	381.410	3.228	1.639	-1.300	1.294
3 FND	13.042	12.931	12.510	12.831	12.979	0.484	-0.369	-3.616	-1.141
4 SFCD	30.200	29.982	30.061	30.097	29.387	2.768	2.027	2.295	2.417
5 P7Q2	1.941	1.932	1.849	1.916	1.907	1.774	1.315	-3.016	0.489
6 T7Q2	2.655	2.653	2.617	2.654	2.645	0.403	0.327	-1.047	0.367
7 P7/pa	2.512	2.528	2.398	2.492	2.479	1.330	1.978	-3.256	0.532
8 NL/NH	0.613	0.612	0.609	0.610	0.601	2.020	1.823	1.341	1.535
9 CD8	0.964	0.951	0.986	0.955	0.952	1.205	-0.142	3.574	0.230
10 CG8	0.950	0.946	0.987	0.951	0.974	-2.436	-2.931	1.347	-2.353
11 ETA	0.997	0.994	0.999	0.992	0.994	0.281	0.032	0.470	-0.203
12 NHD/100	89.000	89.000	89.000	89.000	89.000	0.000	0.000	0.000	0.000
13 NLD/100	54.553	54.448	54.190	54.294	53.473	2.020	1.823	1.341	1.535
14 Ps7/P2	1.755	1.745	1.702	1.735	1.740	0.891	0.291	-2.162	-0.257

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TABLE X. - Continued.

(g) NHRD, 8825; test condition, 8(34.5-1.3-288)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAID	21.312	20.872	21.405	20.777	21.083	1.084	-1.000	1.526	-1.451
2 WFD	259.410	254.398	250.719	253.497	256.829	1.005	-0.946	-2.379	-1.297
3 FND	8.257	8.089	7.932	8.080	8.005	3.149	1.044	-0.910	0.941
4 SFCD	31.398	31.476	31.553	31.342	32.083	-2.136	-1.893	-1.653	-2.310
5 P7Q2	1.878	1.867	1.810	1.852	1.827	2.789	2.201	-0.945	1.365
6 T7Q2	2.686	2.684	2.648	2.681	2.671	0.549	0.484	-0.863	0.386
7 P7/pa	2.412	2.447	2.340	2.409	2.375	1.552	3.021	-1.475	1.438
8 NL/NH	0.612	0.611	0.607	0.609	0.595	2.904	2.694	2.069	2.336
9 CD8	0.965	0.950	0.998	0.954	0.978	-1.354	-2.850	2.079	-2.406
10 CG8	0.951	0.940	0.981	0.950	0.978	-2.811	-3.926	0.265	-2.881
11 ETA	0.992	0.989	1.004	0.987	0.982	0.952	0.727	2.202	0.477
12 NHD/100	88.250	88.250	88.250	88.250	88.250	0.000	0.000	0.000	0.000
13 NLD/100	54.048	53.937	53.609	53.750	52.523	2.904	2.694	2.069	2.336
14 Ps7/P2	1.702	1.688	1.668	1.642	1.667	2.111	1.270	0.017	-1.541

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(h) NHRD, 8750; test condition, 9(20.7-1.3-288)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAID	12.144	11.839	11.726	11.775	11.834	2.616	0.043	-0.915	-0.501
2 WFD	160.268	156.961	154.531	156.780	156.785	2.222	0.112	-1.438	-0.003
3 FND	4.719	4.513	4.538	4.630	4.582	2.980	-1.521	-0.969	1.034
4 SFCD	33.974	34.783	34.072	33.875	34.214	-0.702	1.662	-0.417	-0.992
5 P7Q2	1.820	1.805	1.766	1.797	1.792	1.581	0.754	-1.408	0.312
6 T7Q2	2.789	2.787	2.737	2.779	2.767	0.799	0.736	-1.072	0.431
7 P7/pa	2.377	2.370	2.300	2.339	2.329	2.050	1.769	-1.270	0.407
8 NL/NH	0.613	0.612	0.608	0.610	0.601	2.024	1.764	1.185	1.455
9 CD8	0.965	0.948	0.950	0.947	0.950	1.599	-0.197	-0.051	-0.323
10 CG8	0.949	0.925	0.955	0.946	0.955	-0.641	-3.133	0.005	-0.977
11 ETA	0.977	0.972	0.950	0.964	0.962	1.613	1.092	-1.197	0.219
12 NHD/100	87.500	87.500	87.500	87.500	87.500	0.000	0.000	0.000	0.000
13 NLD/100	53.654	53.517	53.212	53.355	52.589	2.024	1.764	1.185	1.455
14 Ps7/P2	1.650	1.632	1.633	1.635	1.635	0.920	-0.174	-0.105	0.009

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TABLE X. - Concluded.

(i) NHRD, 8875; test condition, 10(82.7-1.7-288)

	Actual values				Percent, differences from reference				
	NASA 1	AEDC	CEPR	RAE	REF	DIF-L	DIF-A	DIF-F	DIF-R
1 WAID	53.015	52.353	52.000	51.837	51.571	2.800	1.517	0.832	0.515
2 WFD	593.841	588.832	566.190	584.212	581.234	2.169	1.307	-2.588	0.512
3 FND	19.315	19.336	18.472	19.152	19.157	0.821	0.933	-3.577	-0.029
4 SFCD	30.749	30.466	30.638	30.485	30.340	1.347	0.413	0.980	0.478
5 P7Q2	1.857	1.901	1.812	1.878	1.873	-0.849	1.497	-3.243	0.281
6 T7Q2	2.542	2.578	2.541	2.572	2.577	-1.393	0.041	-1.433	-0.220
7 P7/pa	3.134	3.253	3.069	3.206	3.184	-1.581	2.179	-3.616	0.690
8 NL/NH	0.610	0.609	0.606	0.607	0.599	1.792	1.683	1.122	1.356
9 CD8	0.983	0.955	0.987	0.958	0.955	2.838	-0.006	3.306	0.214
10 CG8	0.987	0.953	0.987	0.960	0.971	1.660	-1.857	1.645	-1.155
11 ETA	0.978	0.998	1.002	0.991	0.995	-1.727	0.256	0.752	-0.354
12 NHD/100	88.750	88.750	88.750	88.750	88.750	0.000	0.000	0.000	0.000
13 NLD/100	54.113	54.055	53.756	53.882	53.160	1.792	1.683	1.122	1.358
14 Ps7/P2	1.723	1.719	1.666	1.702	1.709	0.811	0.575	-2.522	-0.413

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TABLE XI. - SEA-LEVEL FACILITY COMPARISON

[Reference, math model; independent variable, NHRD = 8900;
test condition, sea level (101.3-1.0-288).

(a) Engine, S/N F-615037

	Actual values			Percent, differences from reference			
	NRCC 1	CEPR	TUAF	REF	DIF-C	DIF-F	DIF-T
1 WAID	62.168	62.949	65.729	63.782	-2.530	-1.306	3.053
2 WFD	683.331	668.797	730.141	687.115	-0.551	-2.666	6.262
3 FND	30.649	30.415	32.372	31.329	-2.172	-2.915	3.330
4 SFCD	22.330	22.078	22.537	21.932	1.814	0.667	2.757
5 P7Q2	1.857	1.842	1.942	1.883	-1.365	-2.144	3.135
6 T7Q2	2.492	2.504	2.511	2.514	-0.892	-0.421	-0.124
7 P7/pa	1.866	1.866	1.942	1.883	-0.890	-0.892	3.160
8 NL/NH	0.593	0.590	0.598	0.601	-1.274	-1.843	-0.405
9 CD8	0.931	0.955	0.942	0.947	-1.682	0.836	-0.546
10 CG8	0.938	0.946	0.915	0.946	-0.797	0.064	-3.273
11 ETA	0.963	1.000	0.966	0.995	-3.247	0.551	-2.925
12 NHD/100	89.000	89.000	89.000	89.000	0.000	0.000	0.000
13 NLD/100	52.792	52.488	53.256	53.473	-1.274	-1.843	-0.405
14 Ps7/P2	1.711	1.693	1.771	1.718	-0.391	-1.440	3.089

07-26-1985

(b) Engine, S/N P-607594

	Actual values		Percent, differences from reference		
	NRCC 1	CEPR	REF	DIF-C	DIF-F
1 WAID	63.068	64.372	63.782	-1.120	0.925
2 WFD	728.756	714.585	734.896	-0.835	-2.764
3 FND	32.149	32.151	33.115	-2.917	-2.911
4 SFCD	22.675	22.246	22.192	2.177	0.242
5 P7Q2	1.924	1.892	1.940	-0.797	-2.431
6 T7Q2	2.574	2.572	2.609	-1.336	-1.436
7 P7/pa	1.934	1.919	1.940	-0.297	-1.039
8 NL/NH	0.603	0.601	0.601	0.391	0.092
9 CD8	0.926	0.962	0.937	-1.174	2.659
10 CG8	0.925	0.953	0.951	-2.668	0.270
11 ETA	0.971	1.005	0.995	-2.417	1.019
12 NHD/100	89.000	89.000	89.000	0.000	0.000
13 NLD/100	53.682	53.523	53.473	0.391	0.093
14 Ps7/P2	1.731	1.744	1.770	-1.062	-1.484

07-26-1985

TABLE XII. - COMPARISON AT SEA LEVEL OR EQUIVALENT FOR ALL FACILITIES

[Reference, math model; independent variable, NHRD = 8900.]

(a) Engine, S/N F-615037; test condition for AEDC, NRCC 1, CEPR, and TUAF, sea level (101.3-1.0-288); test condition for NASA 1, 3(82.7-1.0-288)

	Actual values				
	NASA 1	AEDC	NRCC 1	CEPR	TUAF
1 WAID	63.717	63.048	62.168	62.949	65.729
2 WFD	703.551	691.317	683.331	668.797	730.141
3 FND	31.618	31.586	30.649	30.415	32.372
4 SFCD	22.279	21.895	22.330	22.078	22.537
5 P7Q2	1.889	1.888	1.857	1.842	1.942
6 T7Q2	2.538	2.532	2.492	2.504	2.511
7 P7/pa	1.894	1.898	1.866	1.866	1.942
8 NL/NH	0.596	0.594	0.593	0.590	0.598
9 CD8	0.948	0.937	0.931	0.955	0.942
10 CG8	0.939	0.939	0.938	0.946	0.915
11 ETA	0.988	0.991	0.963	1.000	0.966
12 NHD/100	89.000	89.000	89.000	89.000	89.000
13 NLD/100	53.029	52.837	52.792	52.488	53.256
14 Ps7/P2	1.733	1.722	1.711	1.693	1.771

	Percent, differences from reference					
	REF	DIF-L	DIF-A	DIF-C	DIF-F	DIF-T
1 WAID	63.782	-0.102	-1.150	-2.530	-1.306	3.053
2 WFD	687.115	2.392	0.612	-0.551	-2.666	6.262
3 FND	31.329	0.923	0.819	-2.172	-2.916	3.330
4 SFCD	21.932	1.580	-0.169	1.814	0.667	2.757
5 P7Q2	1.883	0.303	0.277	-1.365	-2.144	3.135
6 T7Q2	2.514	0.923	0.710	-0.892	-0.421	-0.124
7 P7/pa	1.883	0.605	0.798	-0.890	-0.892	3.160
8 NL/NH	0.601	-0.831	-1.190	-1.274	-1.843	-0.405
9 CD8	0.947	0.114	-1.064	-1.688	0.838	-0.546
10 CG8	0.946	-0.688	-0.706	-0.797	0.054	-3.273
11 ETA	0.995	-0.695	-0.416	-3.247	0.551	-2.925
12 NHD/100	89.000	0.000	0.000	0.000	0.000	0.000
13 NLD/100	53.473	-0.831	-1.190	-1.274	-1.843	-0.405
14 Ps7/P2	1.718	0.865	0.197	-0.391	-1.440	3.089

TABLE XII. - Concluded.

(b) Engine, S/N P-607594; test condition for AEDC, NRCC 1, CEPR, and RAE, sea level (101.3-1.0-288); test condition for NASA 1, 4(82.7-1.0-308)

	Actual values				
	NASA 1	AEDC	NRCC 1	CEPR	RAE
1 WAID	65.182	64.214	63.068	64.372	63.335
2 WFD	758.621	731.496	728.756	714.585	732.639
3 FND	33.380	33.207	32.149	32.151	32.458
4 SFCD	22.704	22.033	22.675	22.246	22.567
5 P7Q2	1.951	1.940	1.924	1.892	1.921
6 T7Q2	2.606	2.602	2.574	2.572	2.617
7 P7/pa	1.954	1.949	1.934	1.919	1.951
8 NL/NH	0.606	0.603	0.603	0.601	0.604
9 CD8	0.952	0.942	0.926	0.962	0.941
10 CG8	0.937	0.942	0.925	0.953	0.937
11 ETA	0.984	1.001	0.971	1.005	0.996
12 NHD/100	89.000	89.000	89.000	89.000	89.000
13 NLD/100	53.978	53.657	53.682	53.523	53.719
14 Ps7/P2	1.777	1.764	1.751	1.744	1.750

	Percent, differences from reference					
	REF	DIF-L	DIF-A	DIF-C	DIF-F	DIF-R
1 WAID	63.782	2.195	0.678	-1.120	0.925	-0.701
2 WFD	734.896	3.228	-0.463	-0.835	-2.764	-0.307
3 FND	33.115	0.799	0.278	-2.917	-2.911	-1.985
4 SFCD	22.192	2.308	-0.717	2.177	0.242	1.690
5 P7Q2	1.940	0.616	0.036	-0.797	-2.431	-0.943
6 T7Q2	2.609	-0.106	-0.282	-1.336	-1.436	0.282
7 P7/pa	1.940	0.733	0.482	-0.297	-1.039	0.592
8 NL/NH	0.601	0.944	0.345	0.391	0.092	0.460
9 CD8	0.937	1.569	0.456	-1.174	2.659	0.438
10 CG8	0.951	-1.411	-0.919	-2.668	0.270	-1.414
11 ETA	0.995	-1.076	0.578	-2.417	1.019	0.101
12 NHD/100	89.000	0.000	0.000	0.000	0.000	0.000
13 NLD/100	53.473	0.944	0.345	0.391	0.093	0.460
14 Ps7/P2	1.770	0.409	-0.326	-1.062	-1.484	-1.103

TABLE XIII. - UETP ALTITUDE FACILITY COMPARISON

[Reference, math model. Average of all test conditions.]

	Average delta					Root mean square delta			
	REF	NASA 1	AEDC	CEPR	RAE	NASA 1	AEDC	CEPR	RAE
1 WA1R	65.641	+0.955	-0.258	+0.814	-0.690	+1.248	+0.963	+1.319	+0.970
2 WFR	845.777	-0.013	-0.697	+0.265	+0.239	+1.206	+1.429	+1.609	+0.902
3 FNR	27.329	+0.053	+0.365	+1.155	+0.694	+0.809	+0.648	+1.357	+1.407
4 SFCR	31.032	-0.197	-1.172	-1.073	-0.583	+1.704	+1.824	+1.789	+1.836
5 P7Q2	2.000	+0.160	+0.698	-1.039	+0.518	+0.711	+0.733	+1.059	+0.706
6 T7Q2	2.765	-0.573	-0.036	+0.019	+0.380	+0.762	+0.348	+0.653	+0.480
7 P7QAMB	2.877	-0.034	+1.357	-1.199	+1.156	+0.925	+1.423	+1.326	+1.301
8 NLQNH	0.611	+0.787	+0.651	+0.608	+0.589	+0.942	+0.859	+0.751	+0.743
9 CD8	0.964	+0.499	-0.964	+1.779	-0.882	+1.194	+1.406	+2.129	+1.226
10 CG8	0.969	-1.282	-1.894	+1.488	-1.485	+1.753	+2.034	+1.579	+1.603
11 ETA	0.986	-0.038	+0.344	+0.551	-0.247	+0.847	+0.524	+1.008	+0.403
12 NHR/100	90.057	-0.300	-0.182	+0.376	+0.039	+0.331	+0.244	+0.461	+0.083
13 NLR/100	55.017	+0.485	+0.468	+0.986	+0.628	+0.738	+0.776	+1.131	+0.773
14 PS7Q2	1.825	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000	+0.000

TABLE XIV. - RANDOM ERROR LIMIT OF CURVE FIT (RELCF)

(a) Average RELCF for altitude conditions; engine, S/N P-607594

Facility		WA1R	WFR	FNR	SFCR	P7Q2	T7Q2	P7QAMB	NLR	CD8	CG8
LeRC	1	0.160	0.255	0.298	0.171	0.162	0.089	0.034	0.279	0.090	0.085
AEDC	2	0.091	0.198	0.257	0.141	0.132	0.096	0.034	0.167	0.070	0.083
CEPr-A	5	0.424	0.885	0.956	0.454	0.470	0.323	0.259	0.630	0.418	0.164
RAE(P)	7	0.185	0.361	0.411	0.219	0.216	0.118	0.074	0.260	0.107	0.097
LERC-2	8	0.215	0.497	0.265	0.396	0.139	0.060	0.034	0.454	0.168	0.106

(b) RELCF for sea level or equivalent conditions; engine, S/N P-607594

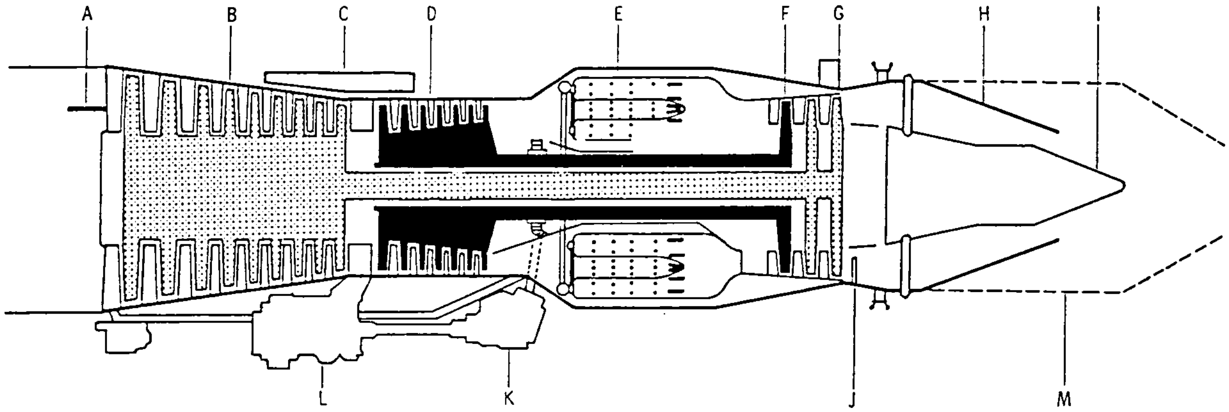
Facility		WA1R	WFR	FNR	SFCR	P7Q2	T7Q2	P7QAMB	NLR	CD8	CG8
LeRC	1	0.280	0.320	0.375	0.055	0.204	0.056	0.029	0.157	0.138	0.069
AEDC	2	0.094	0.205	0.301	0.079	0.157	0.089	0.045	0.178	0.045	0.086
NRCC	3	0.190	0.348	0.396	0.160	0.193	0.044	0.056	0.202	0.092	0.223
CEPr	4	0.319	0.713	0.679	0.194	0.364	0.546	0.220	0.376	0.274	0.061
CEPr-A	5	0.582	0.992	1.151	0.636	0.590	0.289	0.383	0.610	0.100	0.145
RAE(P)	7	0.253	0.303	0.446	0.088	0.277	0.085	0.098	0.295	0.117	0.035
LERC-2	8	0.288	0.505	0.344	0.305	0.165	0.055	0.064	0.605	0.101	0.061

(c) RELCF for sea level or equivalent conditions; engine, S/N F-615037

Facility		WA1R	WFR	FNR	SFCR	P7Q2	T7Q2	P7QAMB	NLR	CD8	CG8
LeRC	1	0.276	0.302	0.349	0.126	0.176	0.071	0.037	0.355	0.362	0.352
AEDC	2	0.107	0.196	0.234	0.098	0.144	0.119	0.025	0.138	0.056	0.056
NRCC	3	0.367	0.527	0.798	0.259	0.436	0.160	0.099	0.434	0.173	0.321
CEPr	4	0.369	0.896	0.878	0.297	0.500	0.303	0.246	0.512	0.111	0.106
TUAF	6	0.261	0.735	0.055	0.043	0.038	0.179	0.086	0.377	0.211	0.304
LERC-2	8	0.189	0.232	0.350	0.164	0.179	0.064	0.065	0.477	0.074	0.079

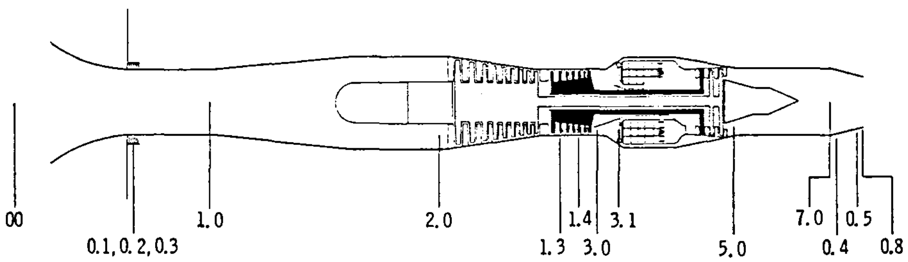
(d) RELCF for sea level or equivalent conditions; average of both engines

Facility		WA1R	WFR	FNR	SFCR	P7Q2	T7Q2	P7QAMB	NLR	CD8	CG8
LeRC	1	0.278	0.311	0.362	0.090	0.292	0.064	0.048	0.256	0.250	0.210
AEDC	2	0.101	0.201	0.268	0.088	0.150	0.104	0.035	0.158	0.050	0.071
NRCC	3	0.278	0.438	0.597	0.210	0.316	0.102	0.078	0.318	0.132	0.272
CEPr	4	0.344	0.804	0.778	0.246	0.432	0.424	0.233	0.444	0.192	0.084
CEPr-A	5	0.582	0.992	1.151	0.636	0.590	0.289	0.383	0.610	1.003	0.145
TUAF	6	0.261	0.735	0.551	0.433	0.383	0.179	0.086	0.377	0.211	0.304
RAE(P)	7	0.253	0.303	0.446	0.088	0.277	0.085	0.098	0.295	0.117	0.035
LERC-2	8	0.238	0.369	0.347	0.234	0.172	0.060	0.064	0.541	0.088	0.070



A. EPR probe (inlet pressure)
B. Low pressure compressor
C. Oil supply tank
D. High pressure compressor
E. Burner cans
F. First stage turbine
G. Second and third stage turbine
H. Nozzle
I. Tail cone
J. EPR probe (exhaust pressure)
K. Accessory drive elbow
L. Accessory drive housing
M. Modified tailpipe and nozzle assembly

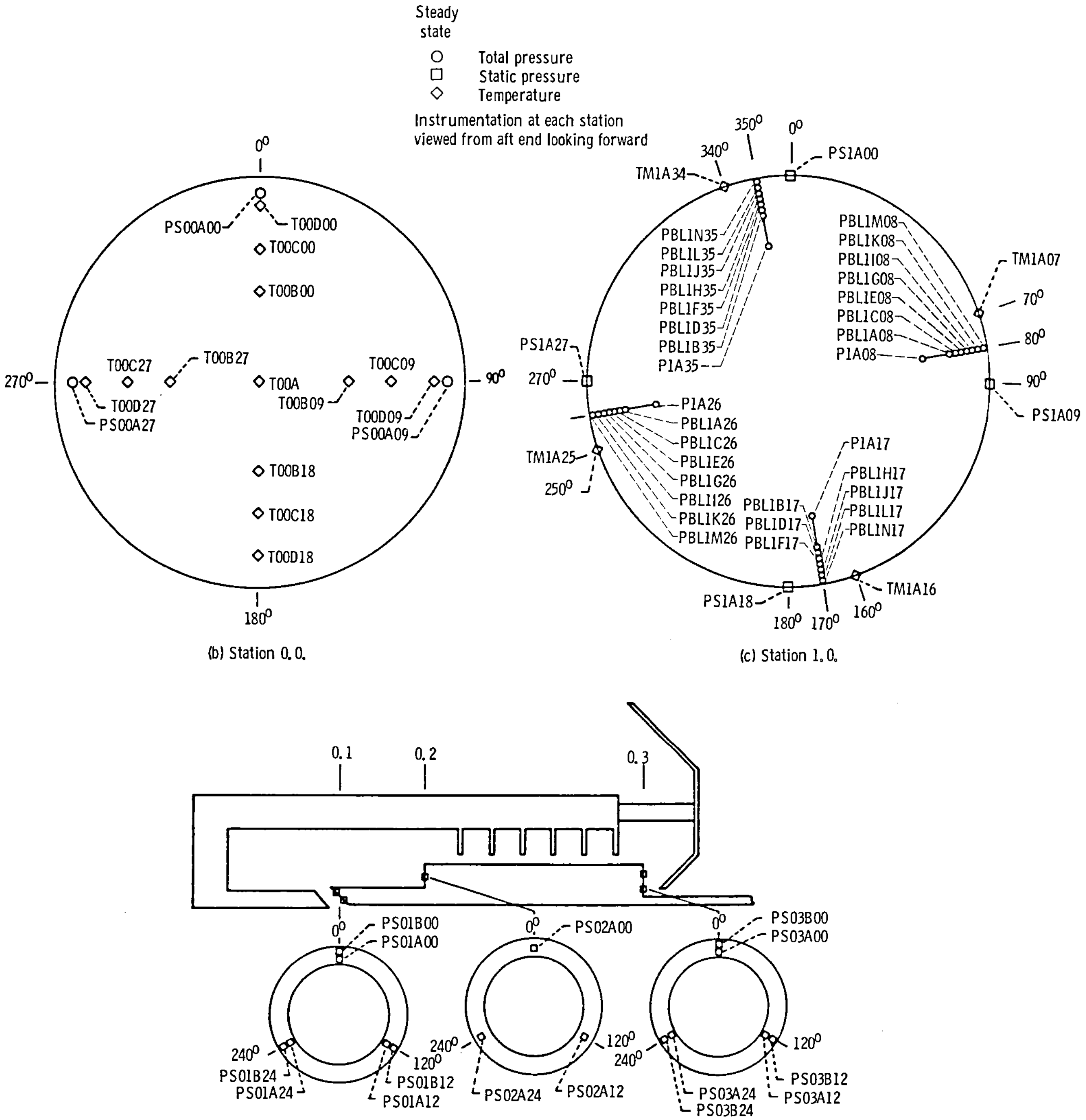
Figure 1. - J57 engine schematic.



Station No.	Description
0.0	Inlet plenum
0.1, 0.2, 0.3	Labyrinth seal
1.0	Airflow station
2.0	Engine or LPC inlet
1.3	LPC bleed annulus
1.4	LPC bleed port
3.0	Combustor inlet
3.1	Combustor diffuser exit
5.0	LPT exit
7.0	Exhaust nozzle inlet
0.4, 0.5, 0.8	Exhaust nozzle (external)

(a) Station locations.

Figure 2. - Instrumentation locations.

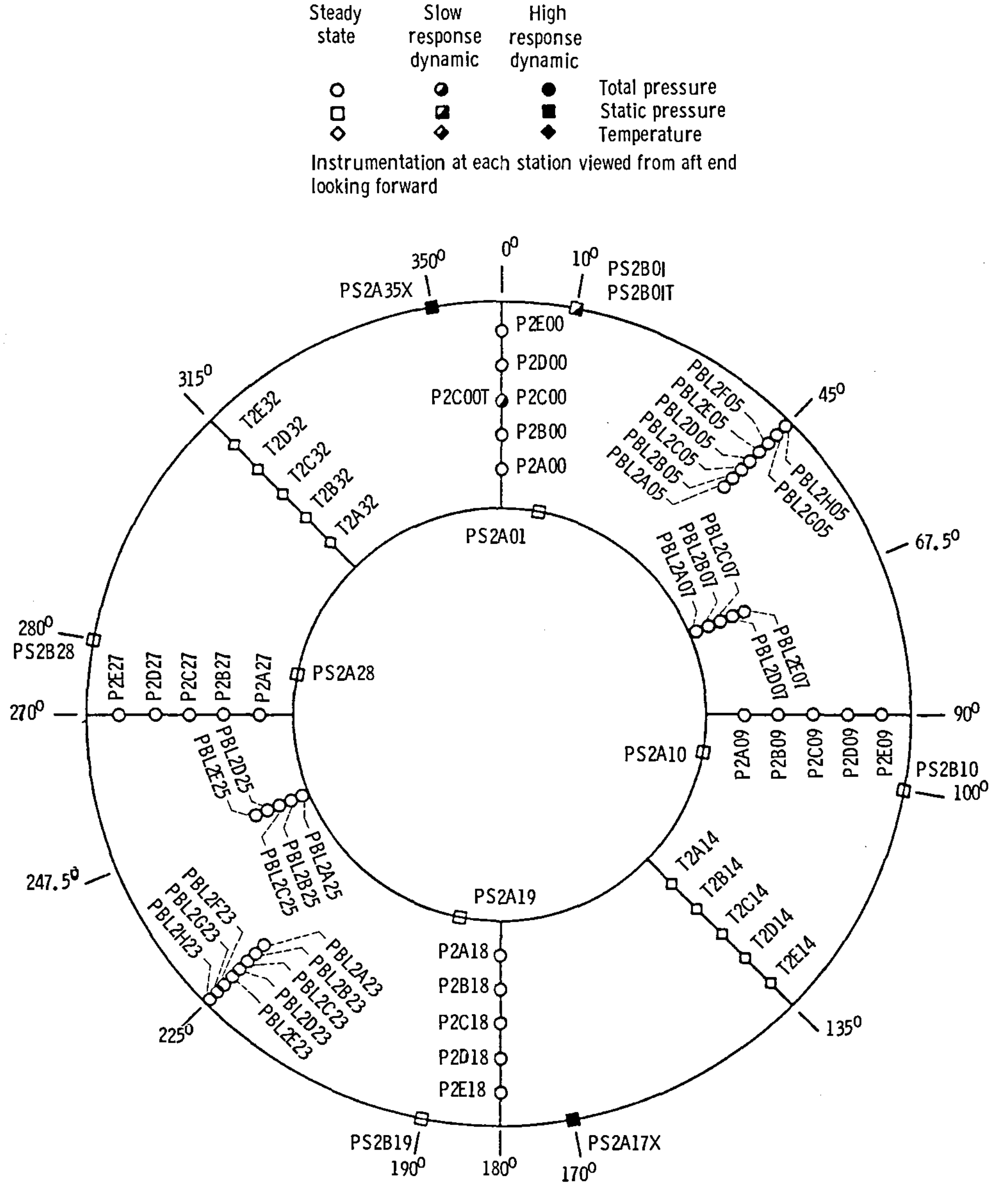


(b) Station 0.0.

(c) Station 1.0.

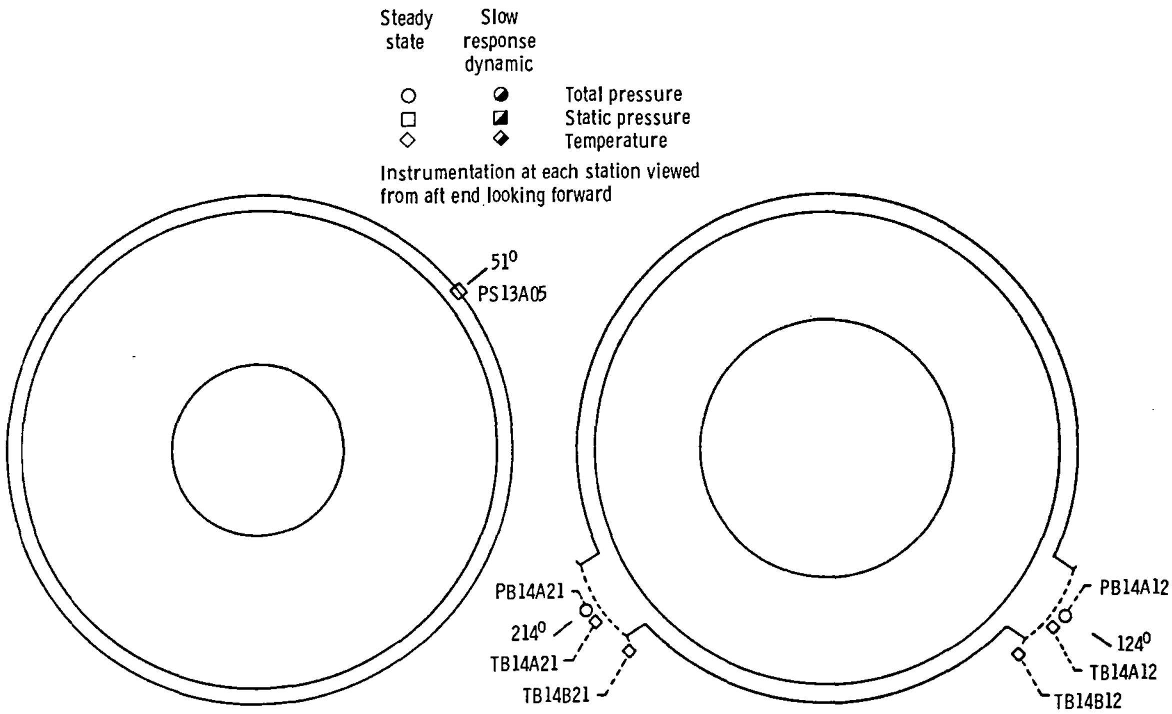
(d) Stations 0.1, 0.2, and 0.3.

Figure 2. - Continued.



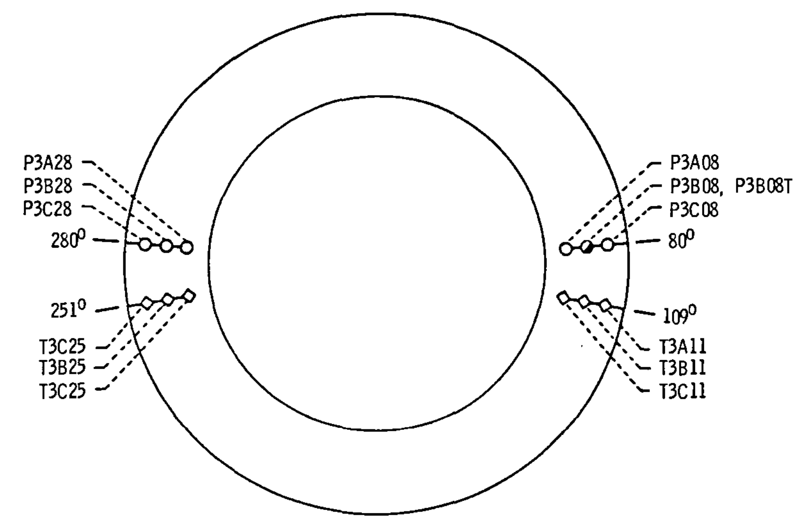
(e) Station 2.0.

Figure 2. - Continued.



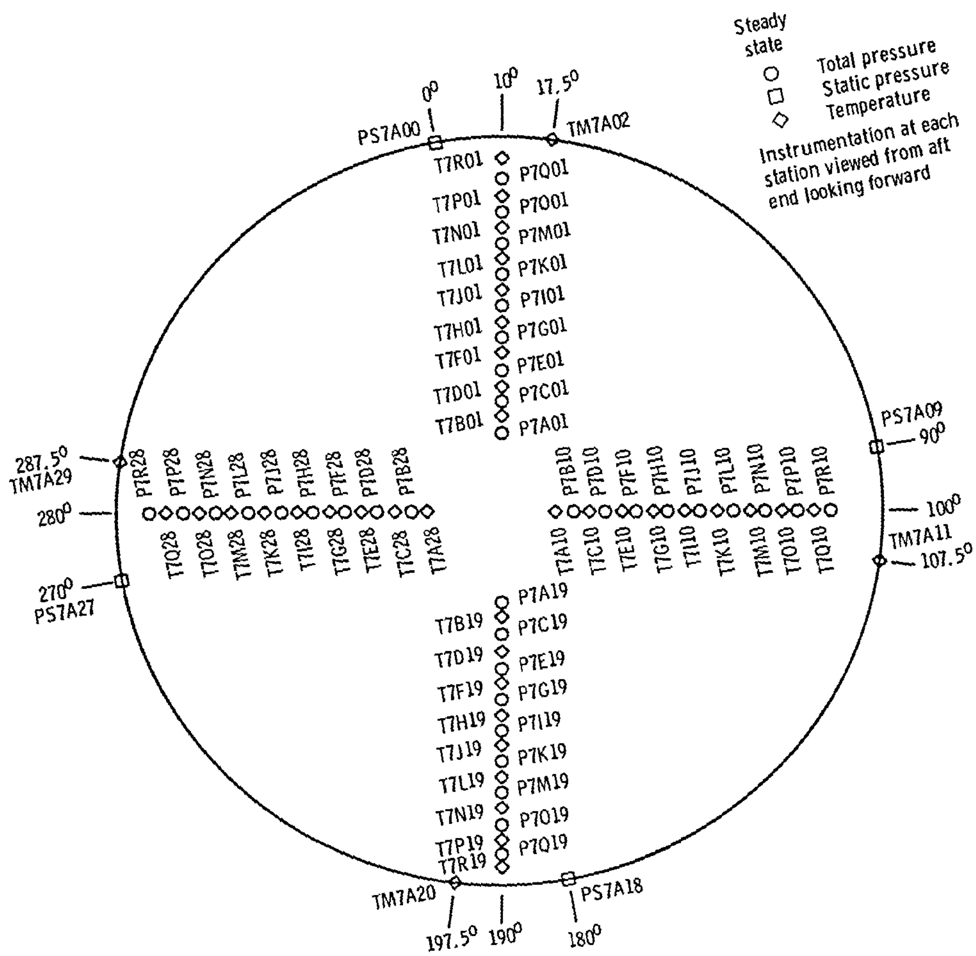
(f) Station 1.3.

(g) Station 1.4.



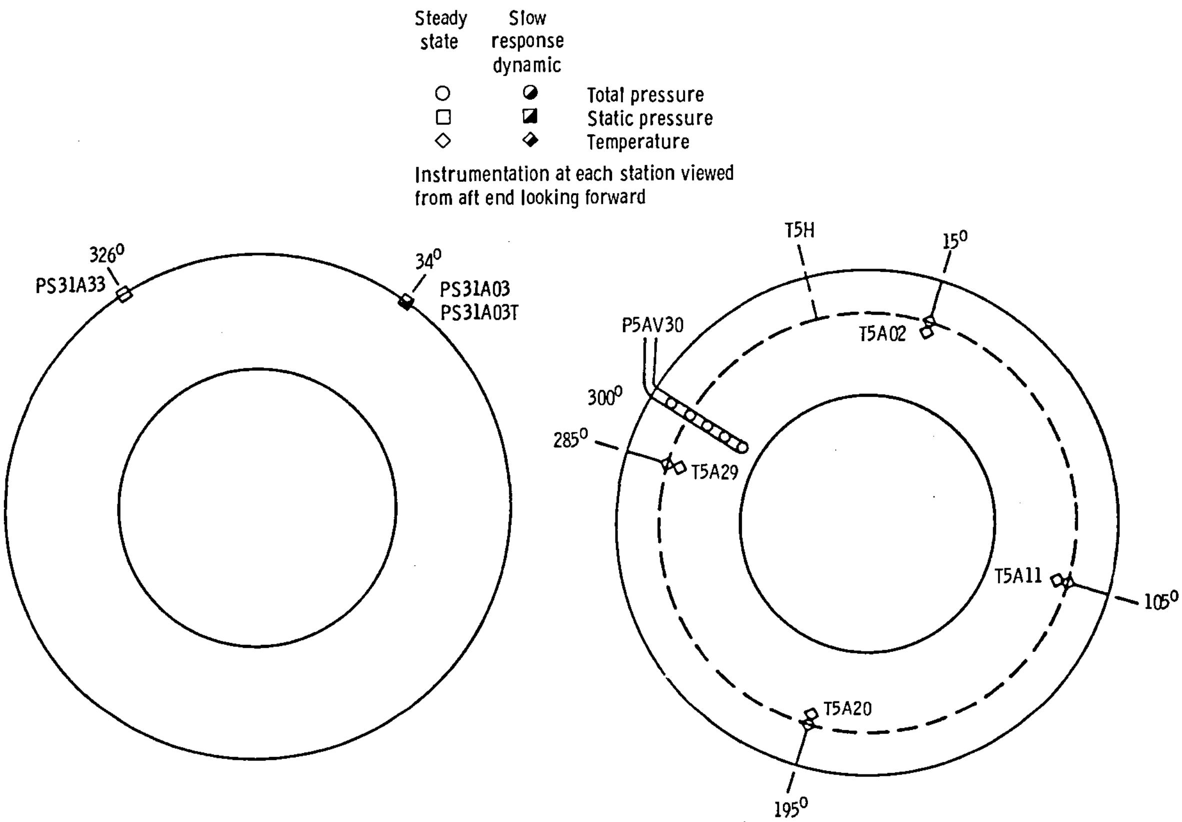
(h) Station 3.0.

Figure 2. - Continued.



(k) Station 7.0.

Figure 2. - Continued.



(i) Station 3.1.

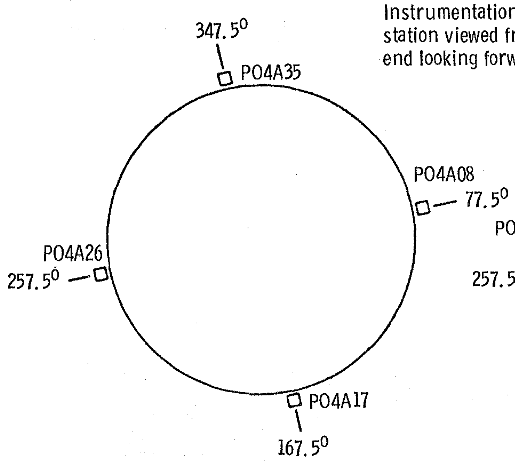
(j) Station 5.0.

Figure 2. - Continued.

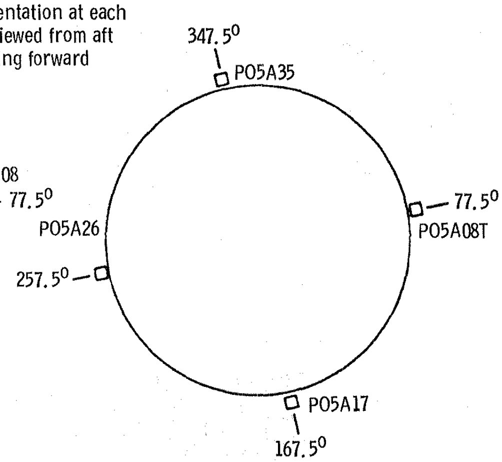
Steady
state

○ Total pressure
□ Static pressure
◇ Temperature

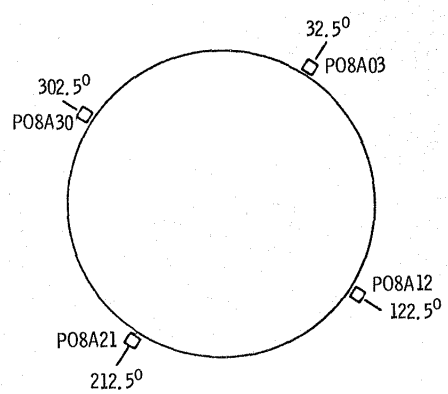
Instrumentation at each station viewed from aft end looking forward



(l) Station 0.4.



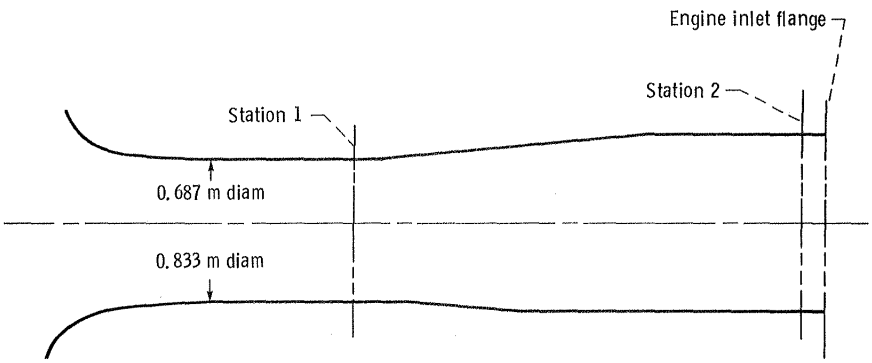
(m) Station 0.5.



(n) Station 0.8.

Figure 2. - Concluded.

NASA UETP standard inlet duct; design M1, 0.6



Larger inlet duct; design M1, 0.36

Figure 3. - Schematics of inlet ducting used for inlet total-pressure profile investigation.

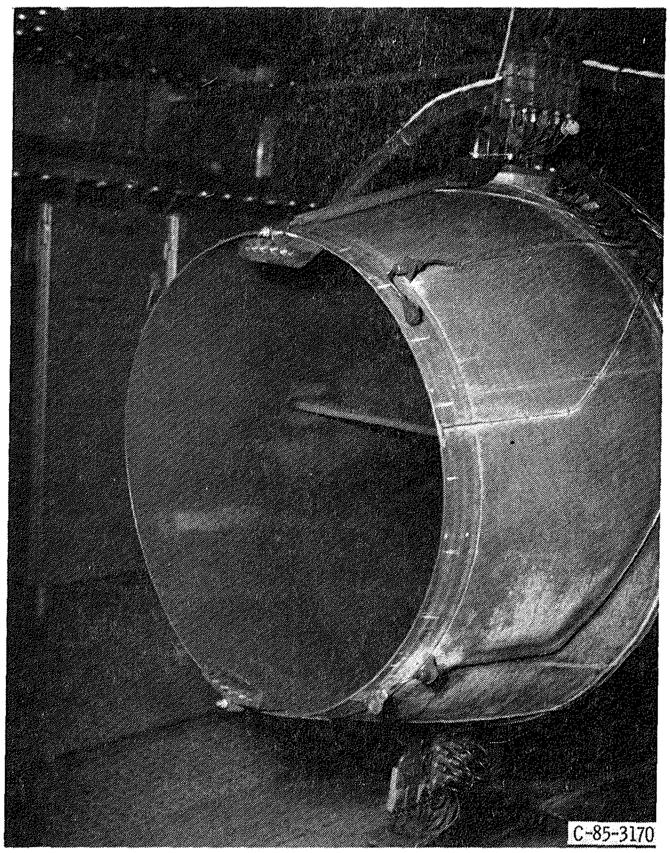


Figure 4. - Engine exhaust nozzle exit area restrictor blocks.

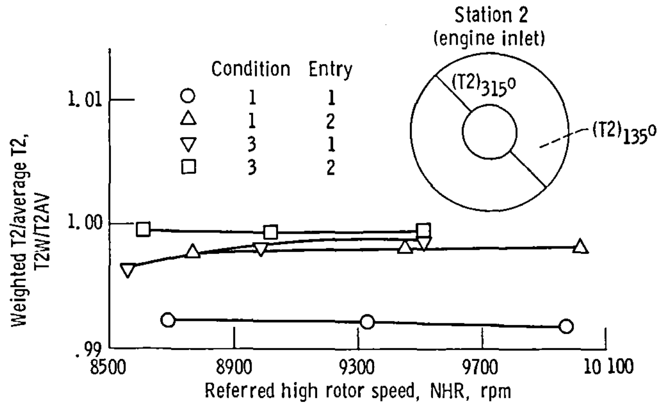


Figure 5. - Comparison of weighted and average engine inlet temperatures. Engine S/N F-615037; ram pressure ratio, 1.0. $T2W = (T2)_{315^0} \cdot (45^0/360^0) + (T2)_{135^0} \cdot (315^0/360^0)$.

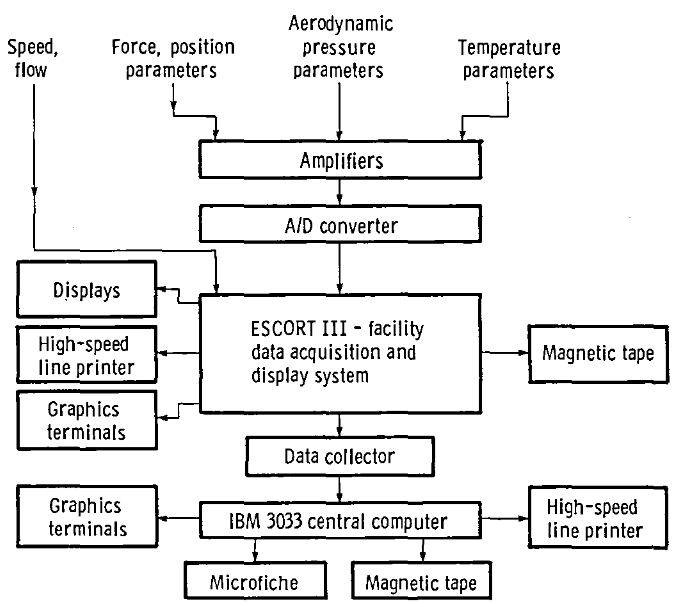


Figure 6. - Digital data acquisition system and data processing system.

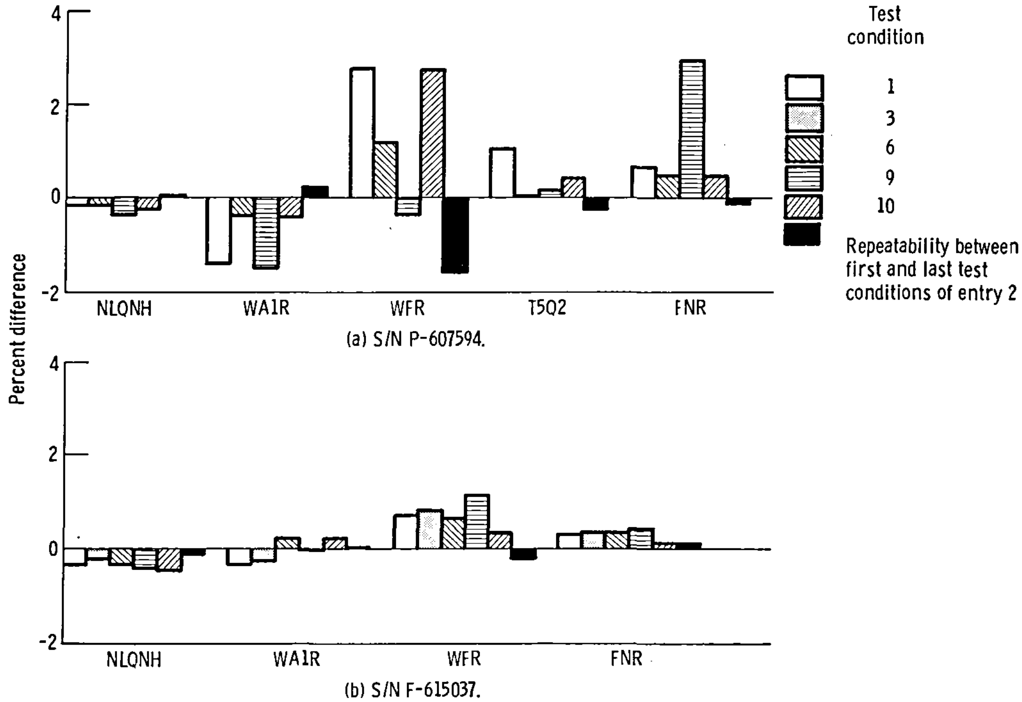


Figure 7. - Differences between NASA entries 1 and 2 for selected test conditions as function of PS7Q2.

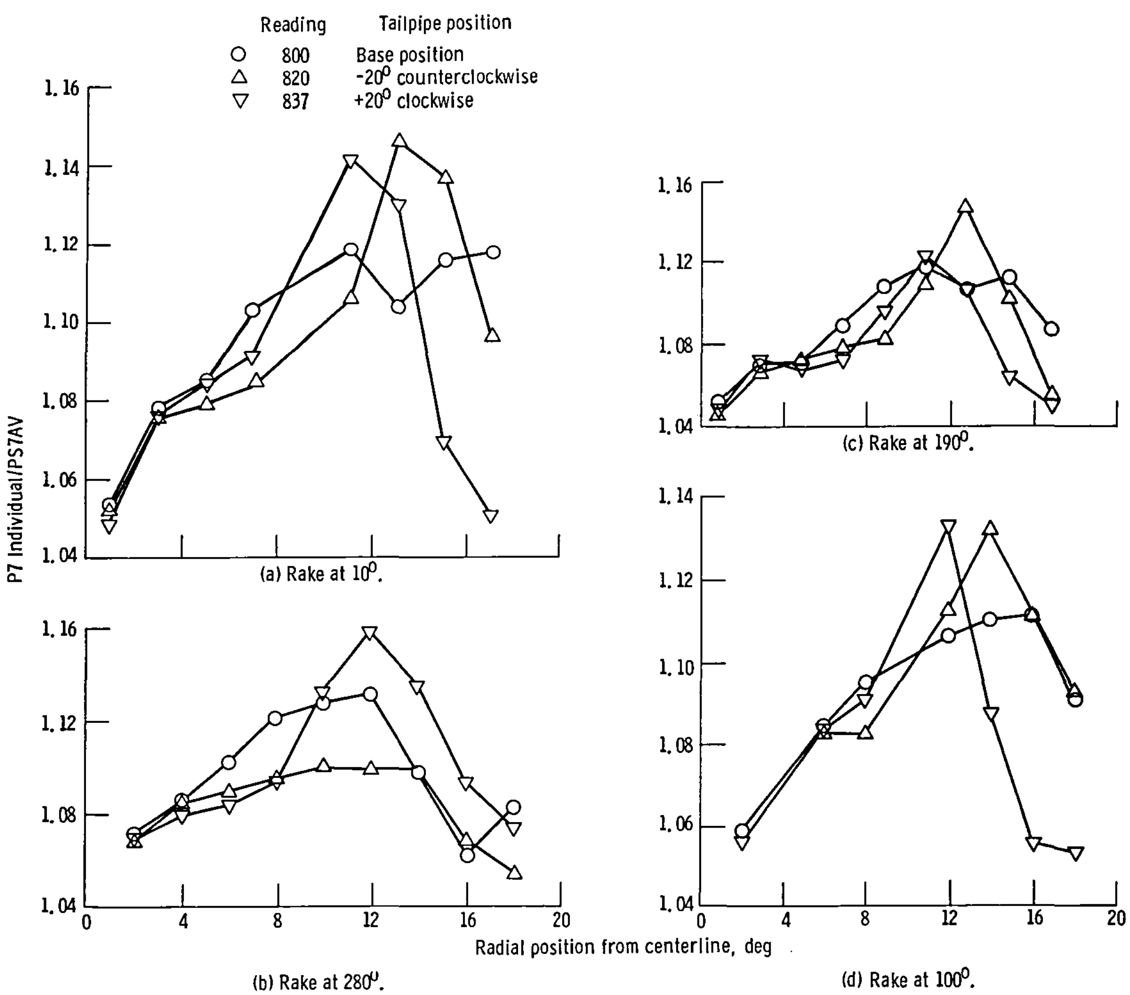
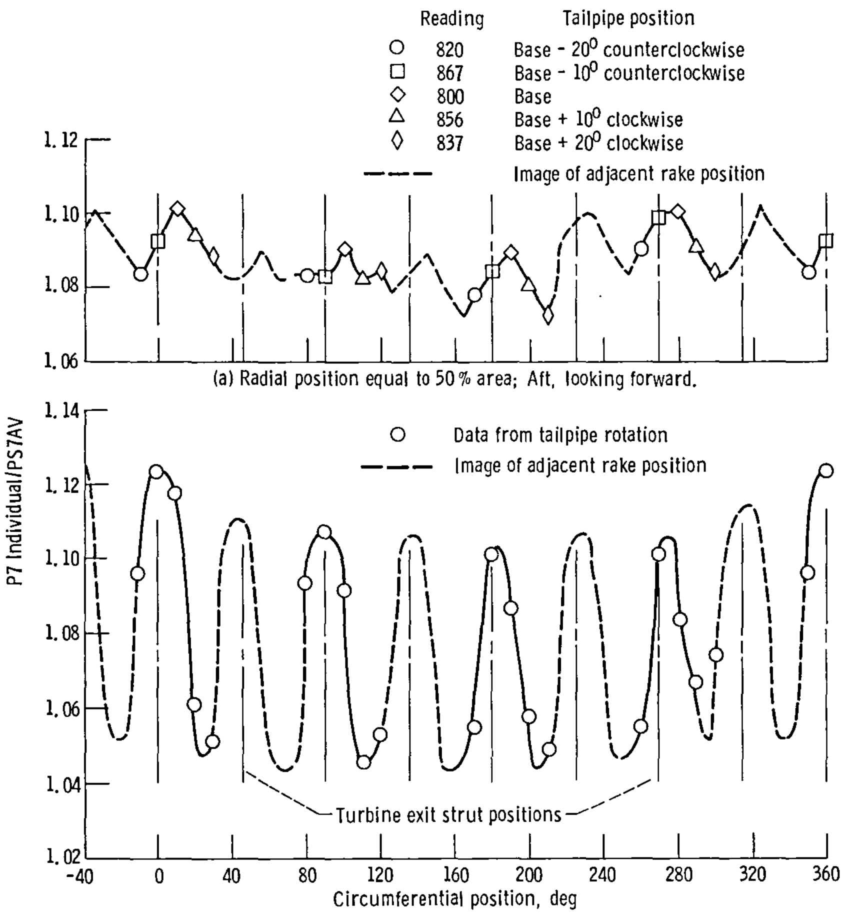


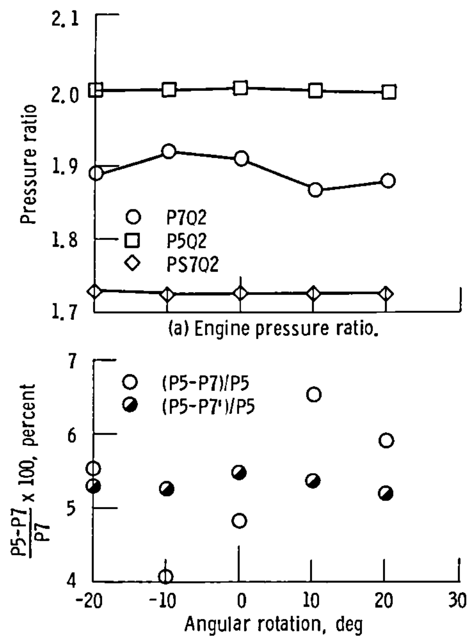
Figure 8. - Station 7 radial total-pressure profiles. UETP condition 6; engine S/N P-607594.



(a) Radial position equal to 50% area; Aft, looking forward.

(b) Radial position at outside diameter.

Figure 9. - Station 7 total pressure variation with tailpipe rotation. Military power; engine S/N P-607594.



(b) Tailpipe pressure loss. P7' = f(PS7, A7/A8).

Figure 10. - Total- and static-pressure variations with tailpipe rotation. Engine S/N P-607594; test condition 6; speed NHR, 8900 rpm.

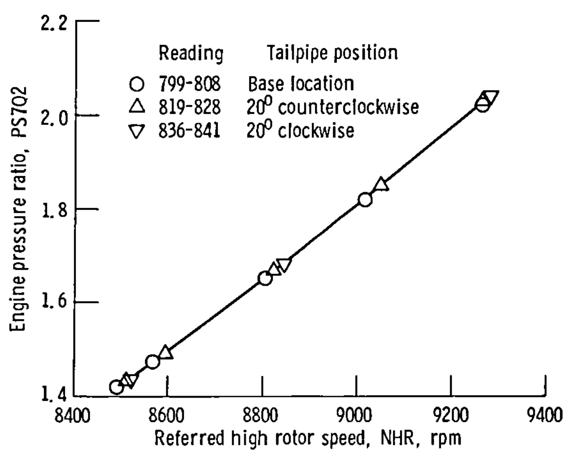
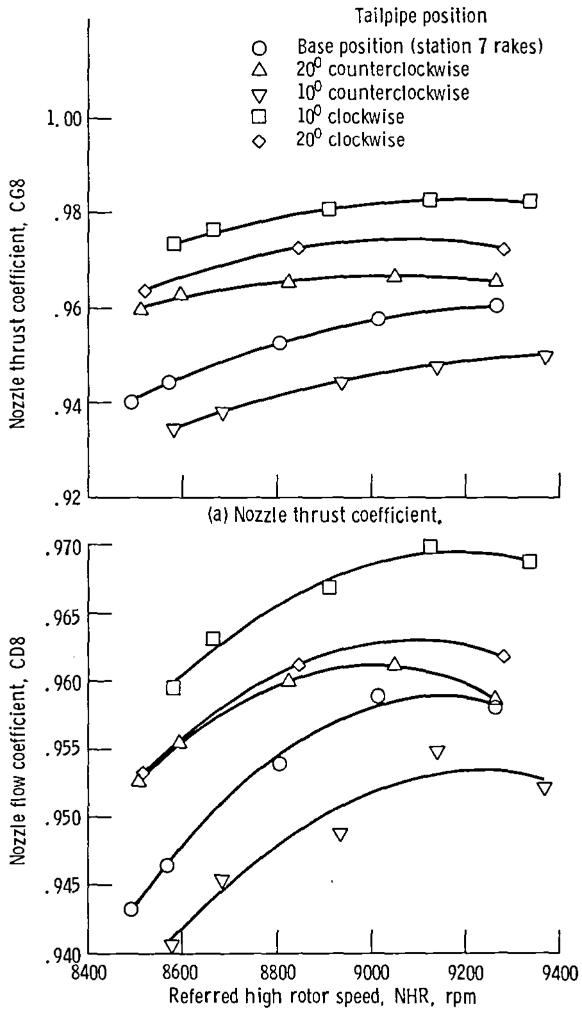
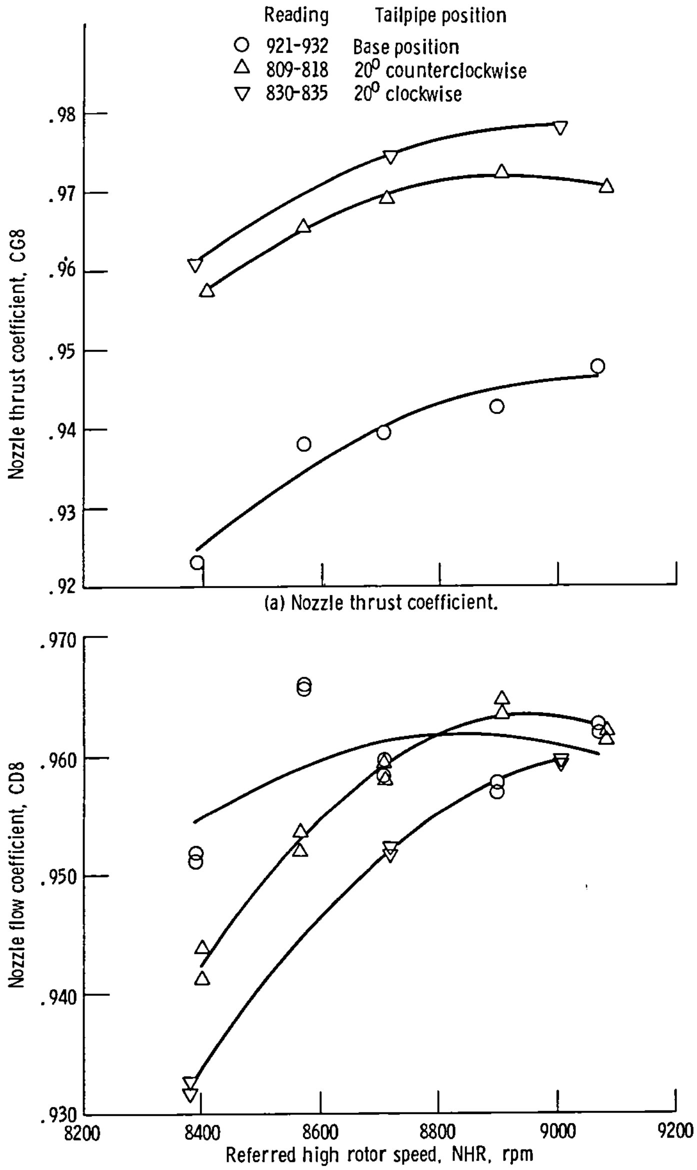


Figure 11. - Effect of tailpipe rotation on engine pressure ratio. Test condition 6; engine S/N P-607594.



(b) Nozzle flow coefficient.

Figure 12. - Effect of tailpipe rotation on thrust and flow. Test condition 6; engine S/N P-607594.



(a) Nozzle thrust coefficient.

(b) Nozzle flow coefficient.

Figure 13. - Effect of tailpipe rotation on thrust and flow. Test condition 9; engine S/N P-607594.

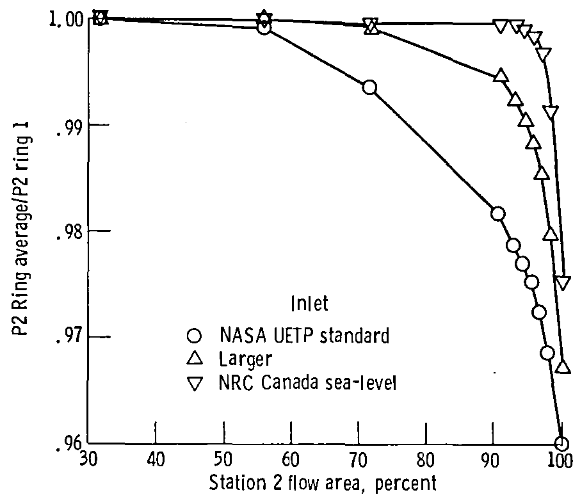


Figure 14. - Effect of inlet duct on station 2 total-pressure profile. Test condition 6; engine S/N P-607594; military power.

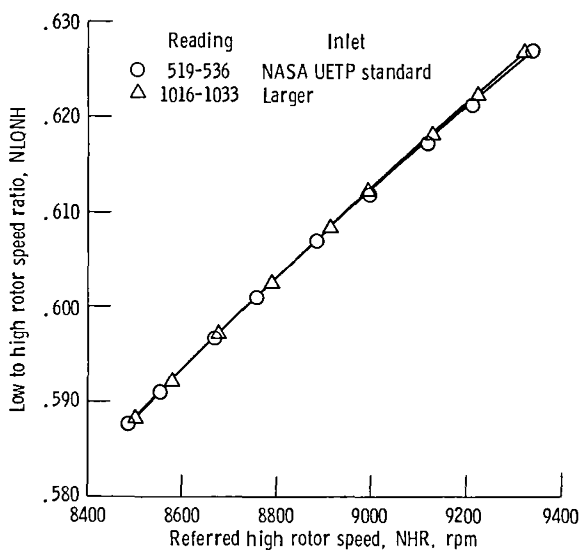


Figure 15. - Effect of inlet duct on speed ratio. Test condition 6; engine S/N P-607594.

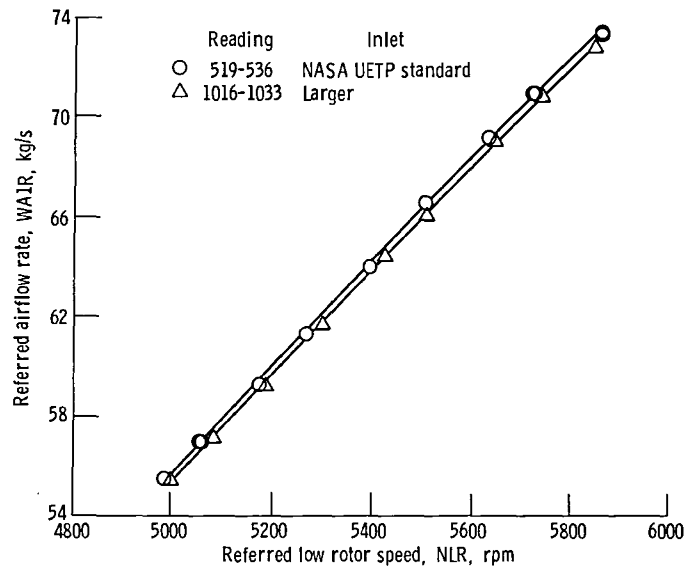


Figure 16. - Effect of inlet duct on total inlet airflow. Test condition 6; engine S/N P-607594.

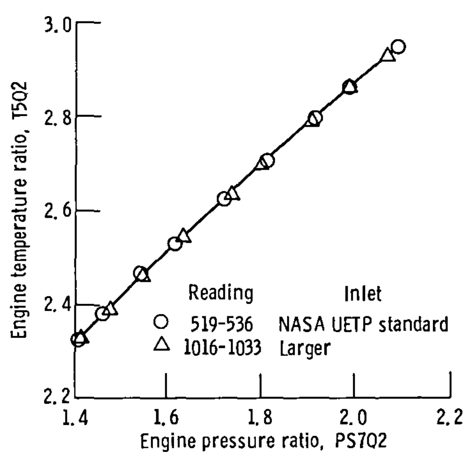


Figure 17. - Effect of inlet duct on engine pumping characteristics. Test condition 6; engine S/N P-607594.

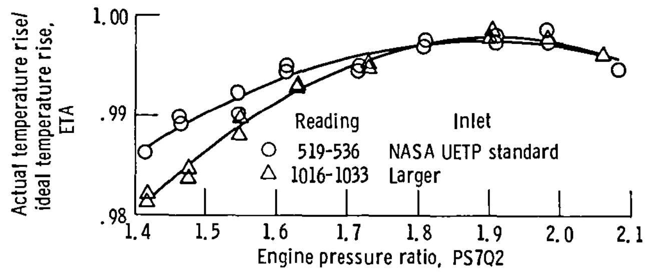


Figure 18. - Effect of inlet duct on engine efficiency. Test condition 6; engine S/N P-607594.

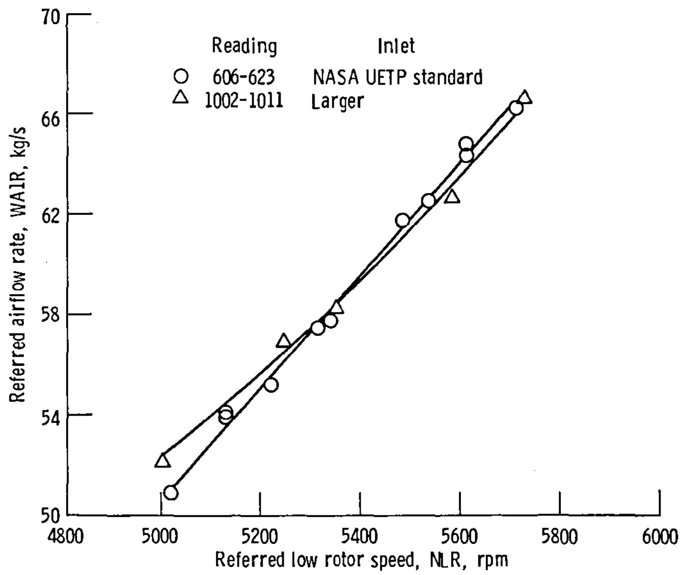


Figure 19. - Effect of inlet duct on total inlet airflow. Test condition 9; engine S/N P-607594.

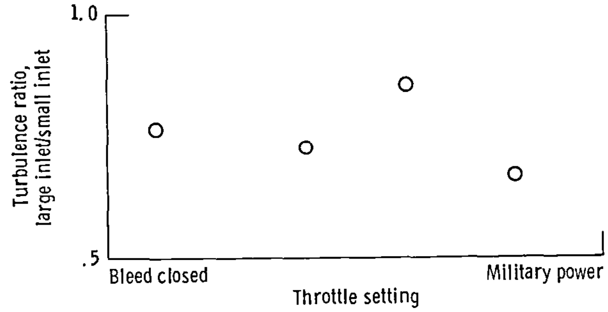


Figure 20. - Variation of turbulence level at engine inlet. Engine S/N P-607594; P2AV, 83 kPa.

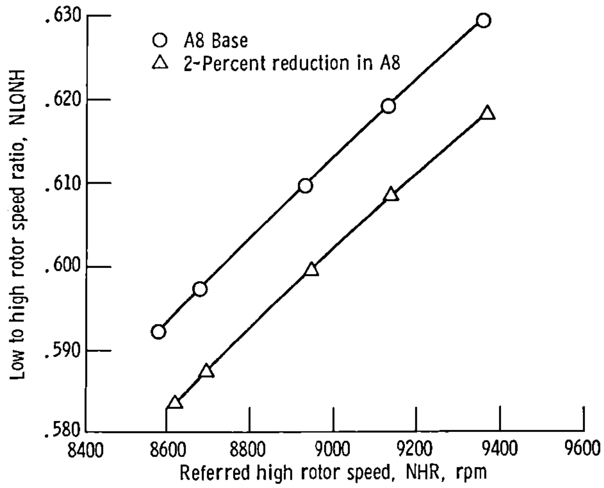


Figure 21. - Effect of exhaust nozzle area (A8) on speed ratio. Test condition 6; engine S/N P-607594.

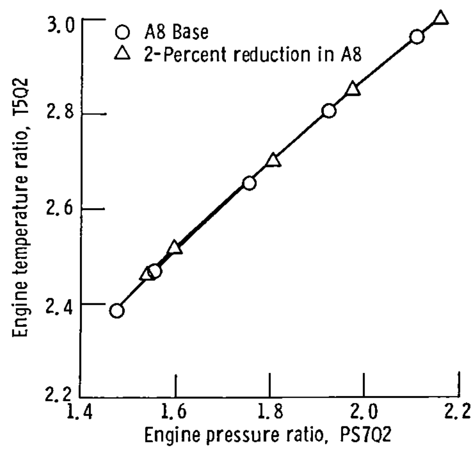


Figure 22. - Effect of exhaust nozzle area (A8) on engine pumping characteristics. Test condition 6; engine S/N P-607594.

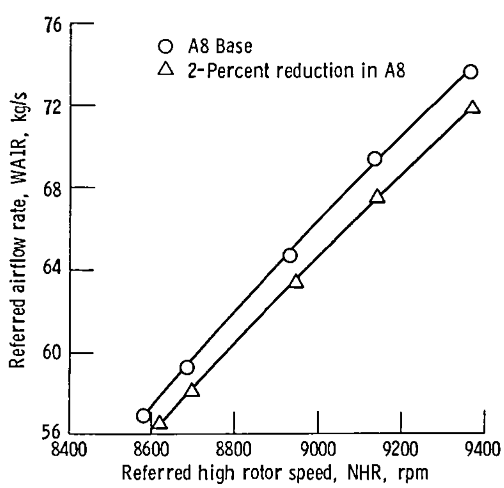


Figure 23. - Effect of exhaust nozzle area (A8) on total inlet airflow at high rotor speed. Test condition 6; engine S/N P-607594.

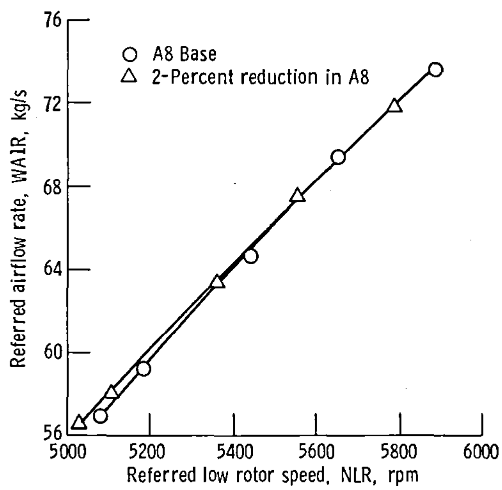
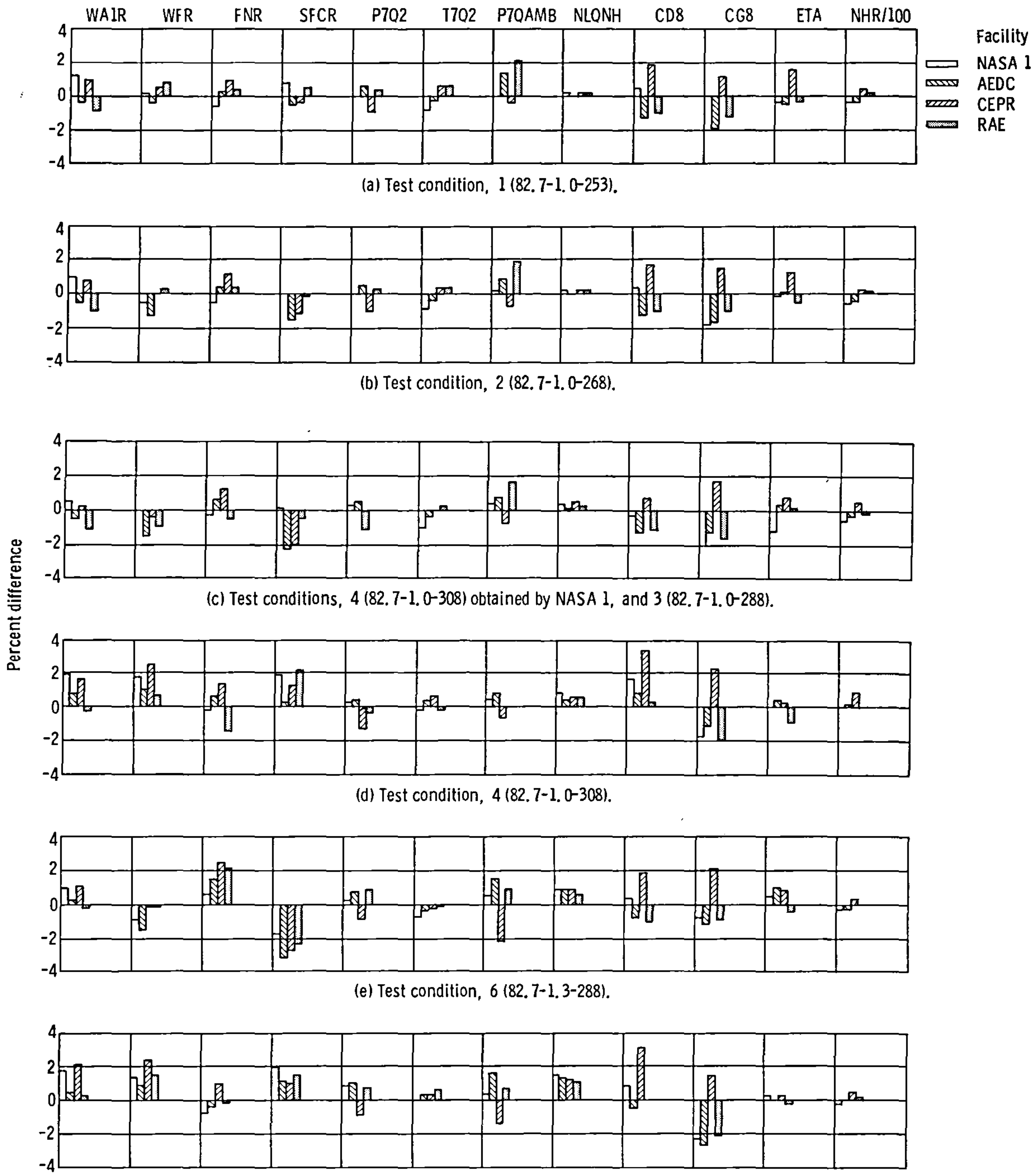


Figure 24. - Effect of exhaust nozzle area (A8) on total inlet airflow at low rotor speed. Test condition 6; engine S/N P-607594.



(a) Test condition, 1 (82.7-1.0-253).

(b) Test condition, 2 (82.7-1.0-268).

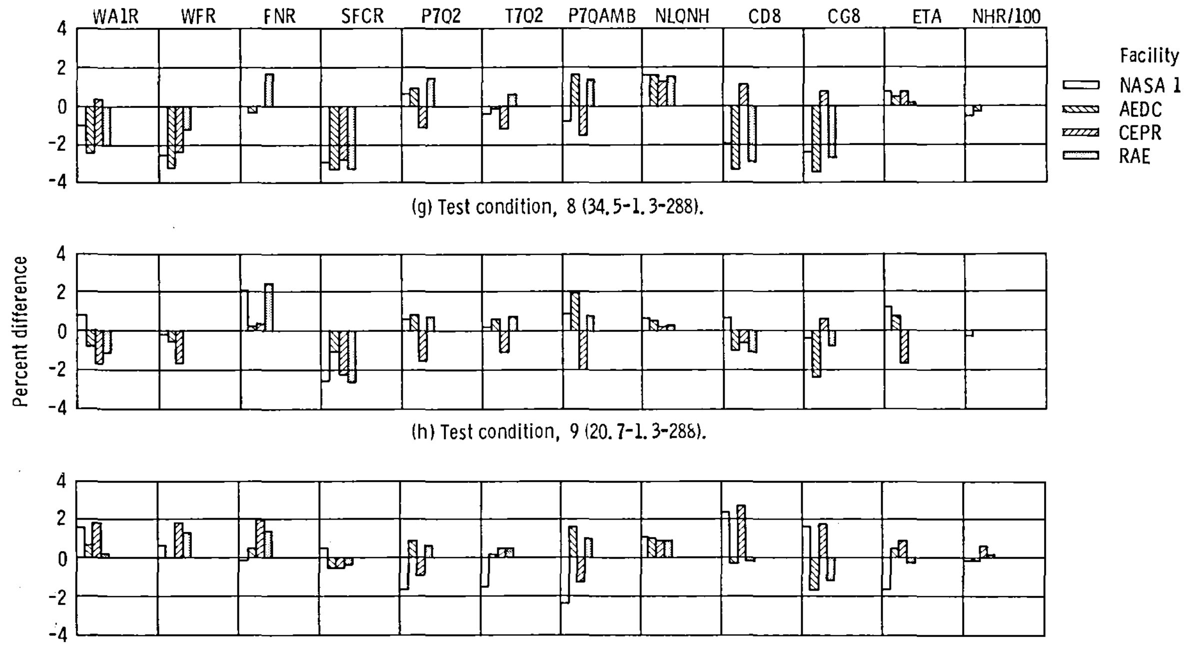
(c) Test conditions, 4 (82.7-1.0-308) obtained by NASA 1, and 3 (82.7-1.0-288).

(d) Test condition, 4 (82.7-1.0-308).

(e) Test condition, 6 (82.7-1.3-288).

(f) Test condition, 7 (51.7-1.3-288).

Figure 25. - UETP altitude facility comparison. Reference, math model; engine, S/N P-607594; constant parameter, PS7Q2 = 1.825.

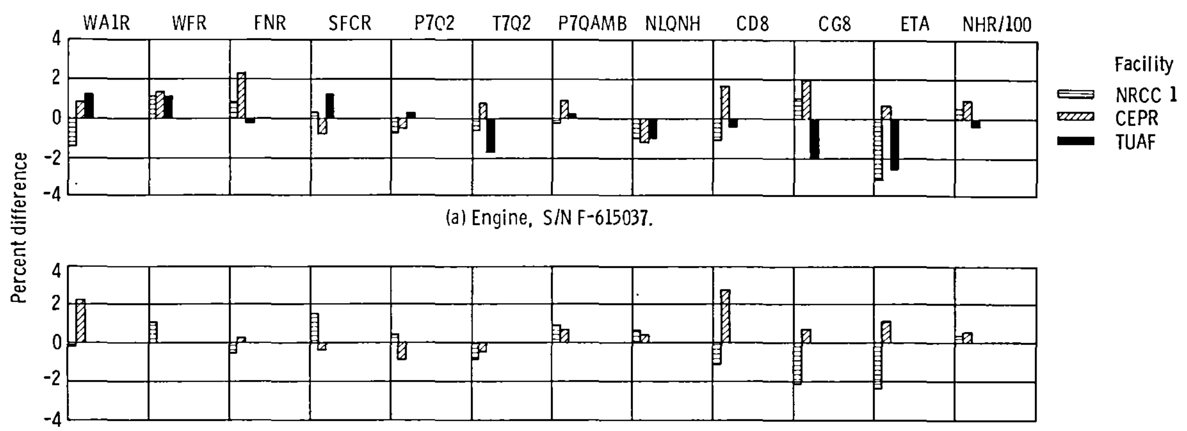


(g) Test condition, 8 (34.5-1.3-288).

(h) Test condition, 9 (20.7-1.3-288).

(i) Test condition, 10 (82.7-1.7-288).

Figure 25. - Concluded.



(a) Engine, S/N F-615037.

(b) Engine, S/N P-607594.

Figure 26. - Sea-level facility comparison. Reference, math model; constant parameter, PS7Q2 = 1.8251; test condition, sea level (101.3-1.0-288).

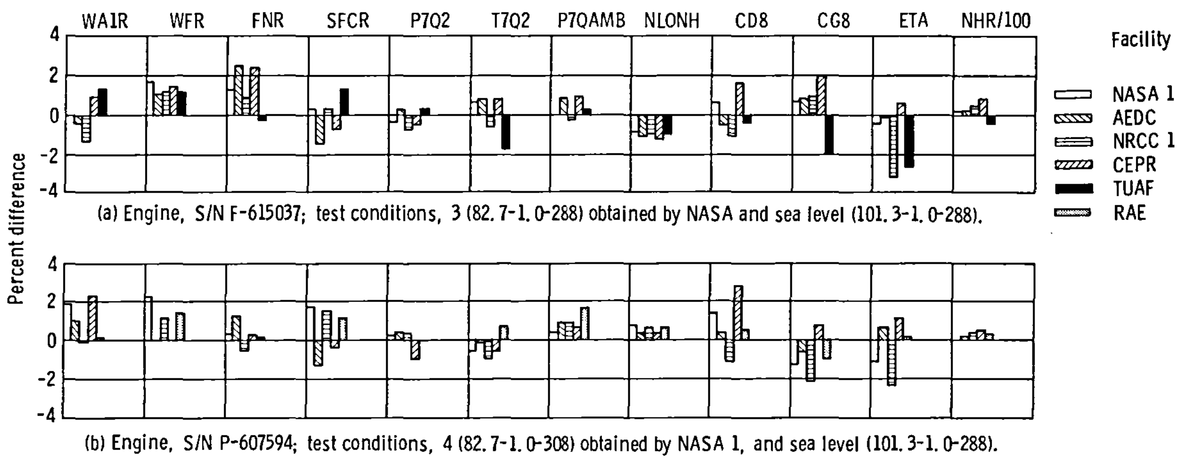


Figure 27. - Comparison at sea level or equivalent for all facilities. Reference, math model; constant parameter, PS7Q2 = 1.8251.

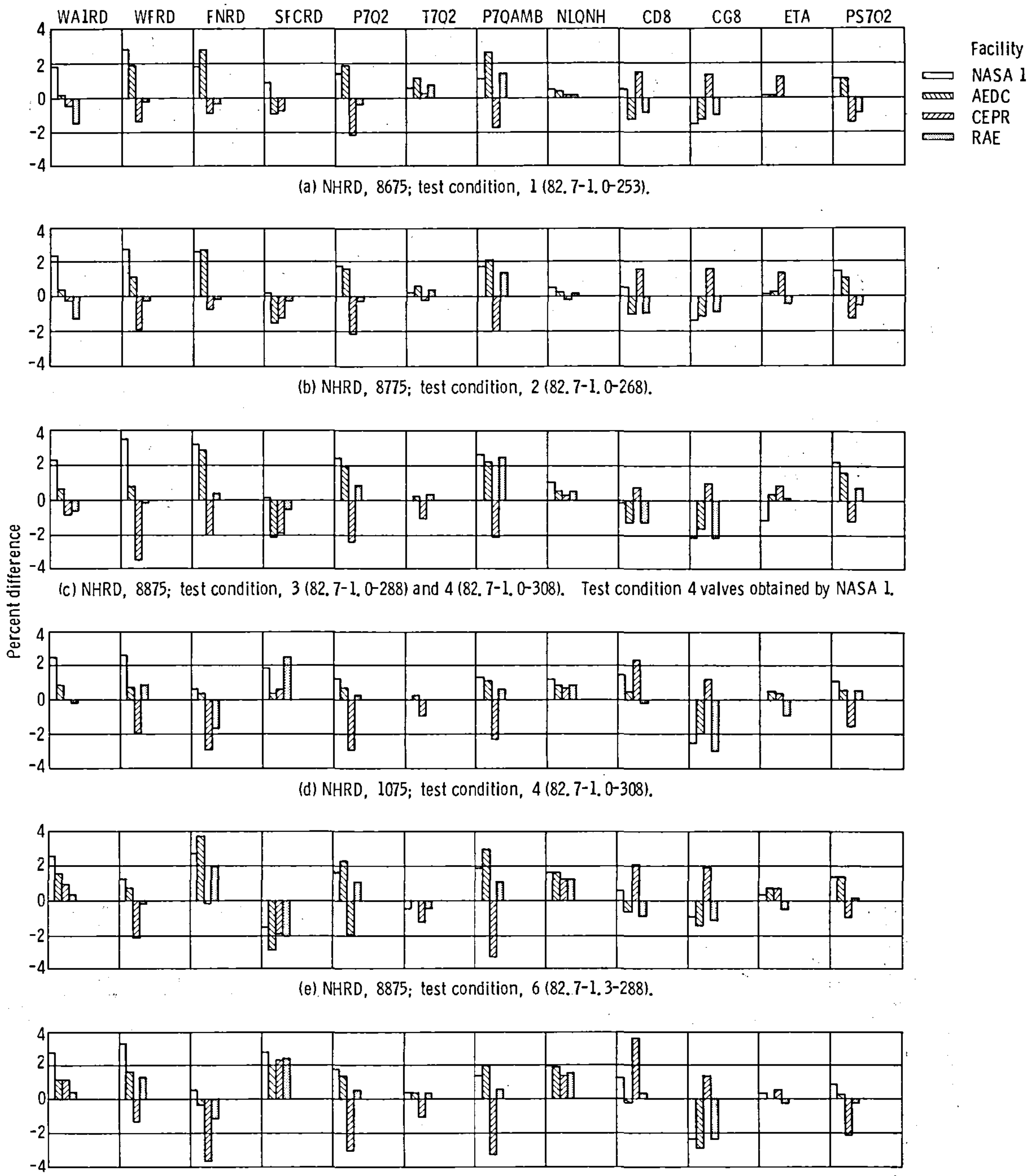
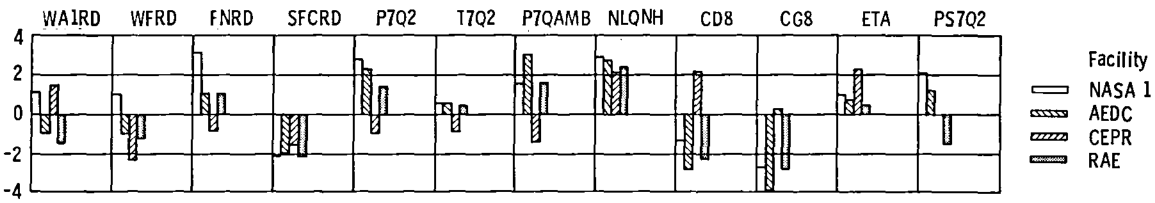
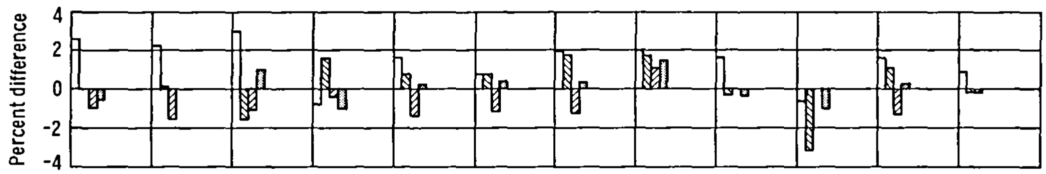


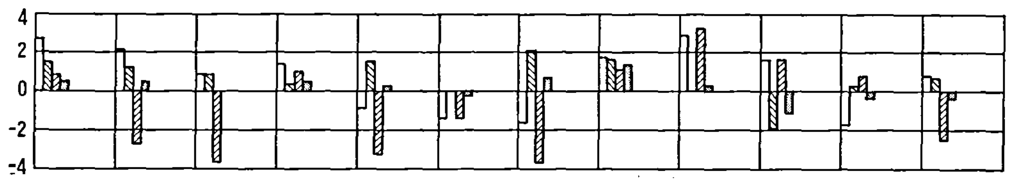
Figure 28. - UETP altitude facility comparison. Reference, math model; engine, S/N P-607594; constant parameter, NHRD.



(g) NHRD, 8825; test condition, 8 (34.5-1.3-288).

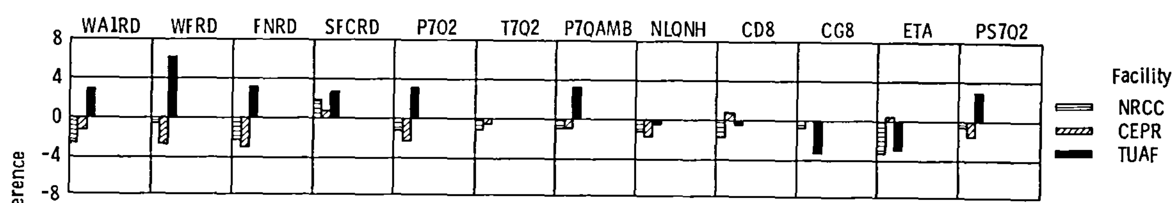


(h) NHRD, 8750; test condition 9 (20.7-1.3-288).

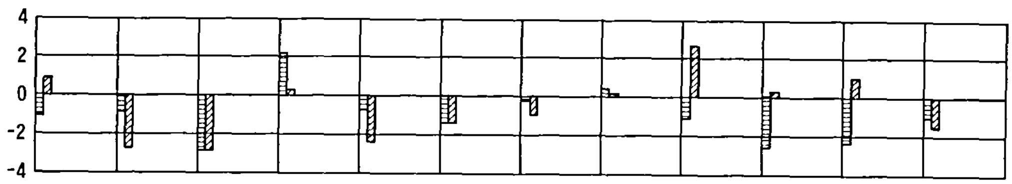


(i) NHRD, 8875; test condition, 10 (82.7-1.7-288).

Figure 28. - Concluded.

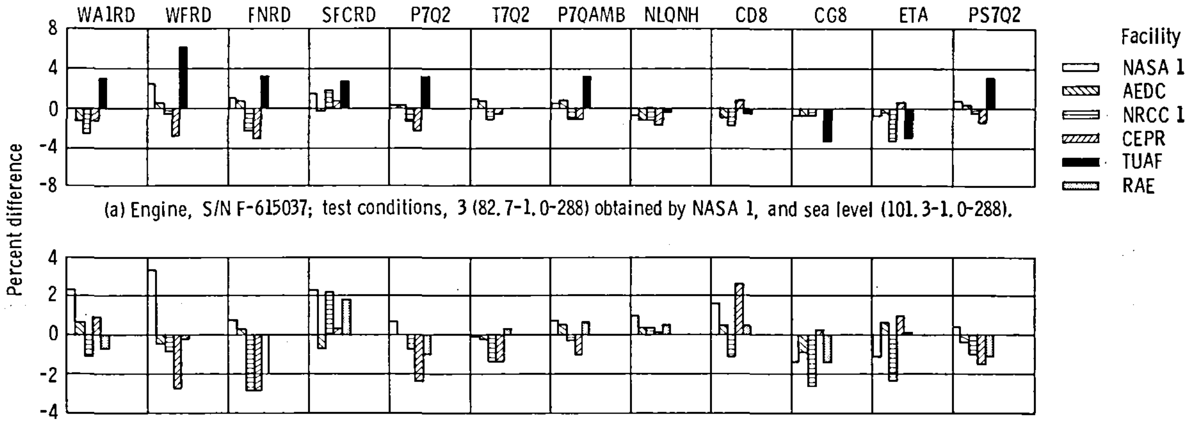


(a) Engine, S/N F-615037.



(b) Engine, S/N P-607594.

Figure 29. - Sea-level facility comparison. Reference, math model; constant parameter, NHRD = 8900; test condition, sea level (101.3-1.0-288).



(a) Engine, S/N F-615037; test conditions, 3 (82.7-1.0-288) obtained by NASA 1, and sea level (101.3-1.0-288).

(b) Engine, S/N P-607594; test conditions, 4 (82.7-1.0-308) obtained by NASA 1, and sea level (101.3-1.0-288).

Figure 30. - Comparison at sea level or equivalent for all facilities. Reference, math model; constant parameter, NHRD = 8900.

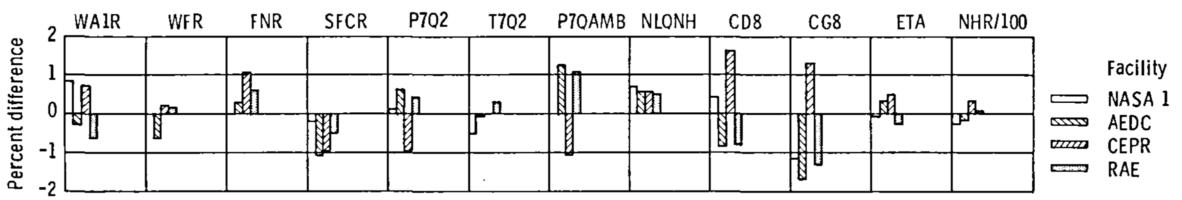


Figure 31. - UETP altitude facility comparison. Average of all test conditions; reference, math model; engine S/N P-607594; constant parameter, PS7Q2 = 1.8251.

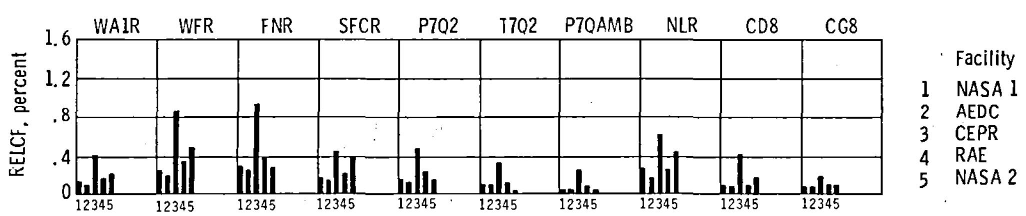


Figure 32. - Average random error limit of curve fit (RELCF) for altitude conditions. Engine, S/N P-607594.

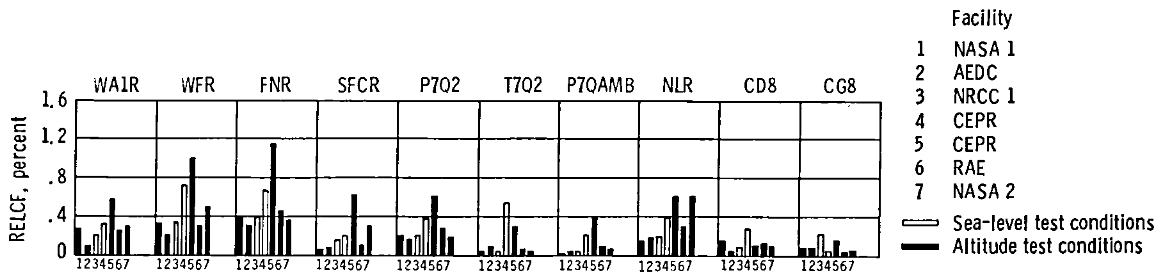


Figure 33. - Average random error limit of curve fit (RELCF) for sea-level or equivalent conditions. Engine, S/N P-607594.

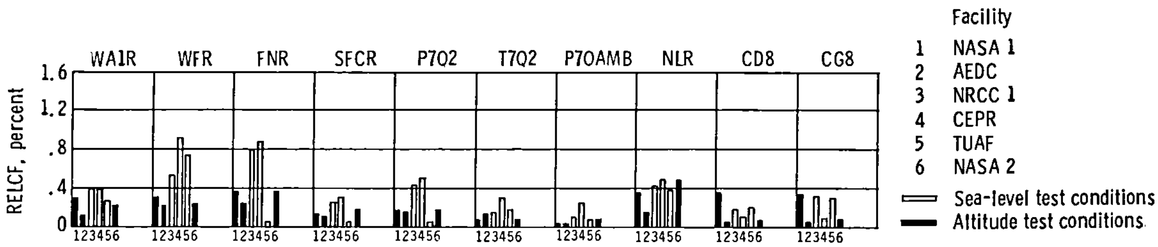


Figure 34. - Average random error limit of curve fit (RELCF) for sea-level or equivalent conditions. Engine, S/N F-615037.

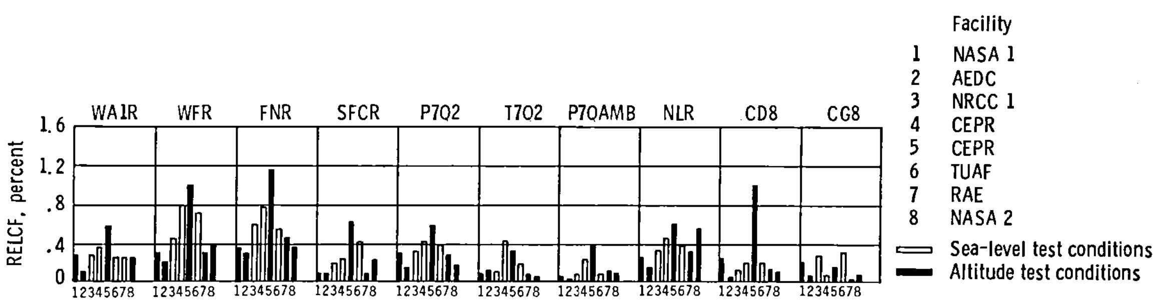


Figure 35. - Average random error limit of curve fit (RELCF) for sea-level or equivalent conditions for both engines.

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15. Supplementary Notes

16. Abstract

The Propulsion and Energetics Panel, Working Group 15, of the Advisory Group for Aerospace Research and Development (AGARD) is sponsoring a Uniform Engine Testing Program (UETP). In this program, two jet engines were tested under identical conditions in certain NATO altitude and ground-level facilities as a means of correlating these facilities. With this second entry, NASA documented engine deterioration that may have occurred since inception of the UETP. Additionally, NASA investigated anomalies discovered during review of data from the five facilities which had participated in the program between the two NASA entries.

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